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SD 70-266
(VCN 24-1C)

SKYLAB PROGRAM
CSM VERIFICATION ANALYSIS REPORT

Part Name EPS Radiator

Part Number V37-458010 & V37-310010

Date September 1970

Prepared by:

J. L. Schaefer

H. A. Vanderpool

15 Sept. 1970
Date

Approved by:

B C Johnson — Mgr. — 17 Sept 1970

System Engineering — Title — Date

J. Bailis — Supv — 9/18/70

Design Assurance — Title — Date

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Space Division
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TECHNICAL REPORT INDEX/ABSTRACT

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*SKYLAB, *RADIATOR, *FUEL CELL,
*TRANSIENT THERMODYNAMIC SIMULATION,
*SINDA COMPUTER PROGRAM

ABSTRACT

THIS DOCUMENT DESCRIBES THE APPLICATION OF THE SINDA COMPUTER PROGRAM FOR THE TRANSIENT THERMODYNAMIC SIMULATION OF THE APOLLO FUEL CELL/RADIATOR SYSTEM FOR THE LIMIT CONDITION OF THE PROPOSED SKYLAB MISSION. RESULTS ARE INCLUDED FOR THE THERMAL CONSTRAINTS IMPOSED UPON THE PRATT AND WHITNEY FUEL CELL POWER CAPABILITY BY THE BLOCK II EPS RADIATOR SYSTEM OPERATING UNDER THE SKYLAB FIXED ATTITUDE ORBITS.

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FOREWORD

The thermal analysis of Skylab fuel cell and radiator system capability, in support of Contract SA500, NAS9-150, was conducted between October 1969 and June 1970. Results of this work are contained in this report, which was prepared by J. L. Schaefer and G. A. Vanderpol of CSM Operations Analysis, Mission Requirements and Evaluation group. The original models of the electrical power system (EPS) radiator and Block I fuel cell, and the CINDA computer program were furnished by H. Cazemier and W. Simon of NASA-MSC. Early checkout runs were limited to leased Univac 1108 service and IBM 7094 emulation, which were slow and expensive. With the assistance of P. Jepsen of Aero and Thermal Projects, Scientific Programming, the IBM 360/SINDA program was obtained and converted to Space Division's IBM 360 formats. E. R. Arnold provided considerable assistance in developing the Block II fuel cell model for the SINDA program.

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1. INTRODUCTION

1.1 PURPOSE OF ANALYSIS

The range of output power capability for the Apollo fuel cell system is established by the requirement to operate within the command module (CM) bus voltage range of 26.5 to 31 volts and by the thermal constraints imposed by the fuel cell stack, condenser, and radiator temperature limits. This report considers only the thermal constraints in establishing the fuel cell power capability for Skylab missions. Under high transient-power levels, CM voltage requirements may be more limiting.

Early in 1969, NASA-MSC personnel furnished for the Skylab study the computer program, the Chrysler Improved Numerical Differencing Analyzer for Third Generation computers (CINDA-3G) (Reference 1), and heat transfer models of the Block II electrical power system (EPS) and the Allis-Chalmers fuel cell system. Subsequently at NR several major changes were made to these models and the CINDA program. The preliminary Allis-Chalmers model became obsolete after the decision was made to use the Pratt and Whitney (PW) Block II fuel cell for the Skylab mission. Therefore, a completely new PW fuel cell model had to be developed for CINDA. Several modifications were made to the EPS radiator model to provide closer correlation with qualification test data (Reference 2) and to include heat transfer between the radiator panels and the service module (SM) structure. Finally, the original CINDA-3G program, which was developed for use on the Univac 1108, was replaced with an advanced program version, Systems Improved Numerical Differencing Analyzer for Third Generator Computers (SINDA-3G), which had been converted (Reference 3) for operation on the IBM 360/75 computer.

1.2 VERIFICATION ANALYSIS REQUIREMENTS

Verification analysis requirements consist of a computer simulation. The simulation determines the effect of the thermal constraints on power capability with one fuel cell and with two fuel cells and with full and five-eighths EPS radiator area operation under the two extremes for Skylab fixed orbit environmental conditions. The SINDA-3G computer program is required for the eight cases of computer simulation. Results for each of the eight cases must be within the acceptable fuel cell temperature limits stated for the flight measurements.

2. CONCLUSIONS

Analysis results indicate the EPS radiator subsystem has sufficient capability to reject the waste heat associated with the fuel cell power levels required for Skylab missions while maintaining the fuel cells within nominal temperature levels. The computer simulation considered sun-vector orbit plane angles (β) of 0.0 and 73.5 degrees for one and two fuel cells operating with full and five-eighths radiator areas. The maximum and minimum power levels evaluated in this study are listed in Table 1. Results are discussed in Section 4.4 of this report.

Table 1. Summary of Results for Fuel Cell/Radiator Power Capability for an Earth Orbit of 235 Nautical Miles

Fuel Cells (number operating)	Radiator Area (operating panels)	Minimum Total Current (amperes)	Maximum Total Current (amperes)
2	8	50	100
2	5	40	90
1	8	30	60
1	5	25	50

3. RECOMMENDATIONS

Based upon results of this analysis, qualification and development test results, and Block II flight data, Block II fuel cell and EPS radiator subsystem capabilities are sufficient to meet Skylab mission requirements. No further testing or analysis is recommended.

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4. ANALYSIS

4.1 ANALYTICAL MODELS

General Fuel Cell Model Considerations

The Pratt and Whitney fuel cell combines oxygen and hydrogen to produce electricity, heat, and water. The overall chemical reaction can be written as

$$H_2 + 1/2\ O_2 \rightarrow H_2O + \text{Energy}$$

The quantity of reactants required to produce a given amount of energy can be determined from Faraday's Laws of Electrolysis. As stated in Reference 4, these are:

1. The mass of a substance liberated in an electrolysis cell is proportional to the quantity of electricity passing through the cell.

2. When the same quantity of electricity is passed through different cells, the masses of the substances liberated are proportional to their electrochemical equivalents.

The combined laws can be used to express the amount of water produced per unit time in terms of current flow:

$$\dot{W}_{H_2O} = I * M/(F * n) \tag{1}$$

where

I = current (amperes)

M = molecular weight

F = Faraday's constant—96500 amp-sec/gm equivalent

n = gm equivalent/gm mole

$\dot{W}$ = weight flow per unit of time

The following values of specific fuel consumption have been determined from the above equation:

0.0230 lb H_2O per amp-hr
0.0204 lb O_2 per amp-hr
0.00257 lb H_2 per amp-hr

Figure 1 depicts the basic schematic of the fuel cell thermodynamic components. Two coolant loops are used to remove the excess heat and water. The stack contains the 31 individual fuel cell elements, each of which consists of two electrodes and the KOH electrolyte, where the chemical reaction of hydrogen and oxygen occurs. Electrically the cells are connected in series. Each is capable of approximately 1 volt, depending on electrolyte condition and load. The temperature of the stack is maintained in the range of 390 to 460 F by means of the primary regenerator and bypass valve. The condenser and water separator are responsible for the water removal and the resulting water concentration in the electrolyte. The temperature range at which water is nominally condensed is 155 to 165 F.

This temperature range is controlled by the secondary regenerator bypass valve and the secondary regenerator. After some of the waste heat is used to heat the incoming reactants in the oxygen and hydrogen preheaters, the EPS radiators reject the excess heat to space. The analytical modeling for each major component is discussed in more detail in the next sections.

Voltage Output

The fuel cell terminal voltage is a function of load current, stack temperature, and electrolyte (KOH) water concentration. Reference 5 provides nominal fuel cell performance curves that depict voltage as a function of current and parametric values of stack (surface) temperature. These curves were expressed in the general polynomial form

$$V_t = A_1 + A_2 I + A_3 I^2 + A_4 I^3 + A_5 TS + A_6 (TS)(I) + A_7 (TS)(I^2) + A_8 TS^2 + A_9 (I)(TS^2) + A_{10} TS^3 \quad (2)$$

where

V_t is voltage based on current and stack temperature (volts)

$A_1 \ldots\ldots A_{10}$ are coefficients

I = load current (amperes)

TS = stack temperature (°F)

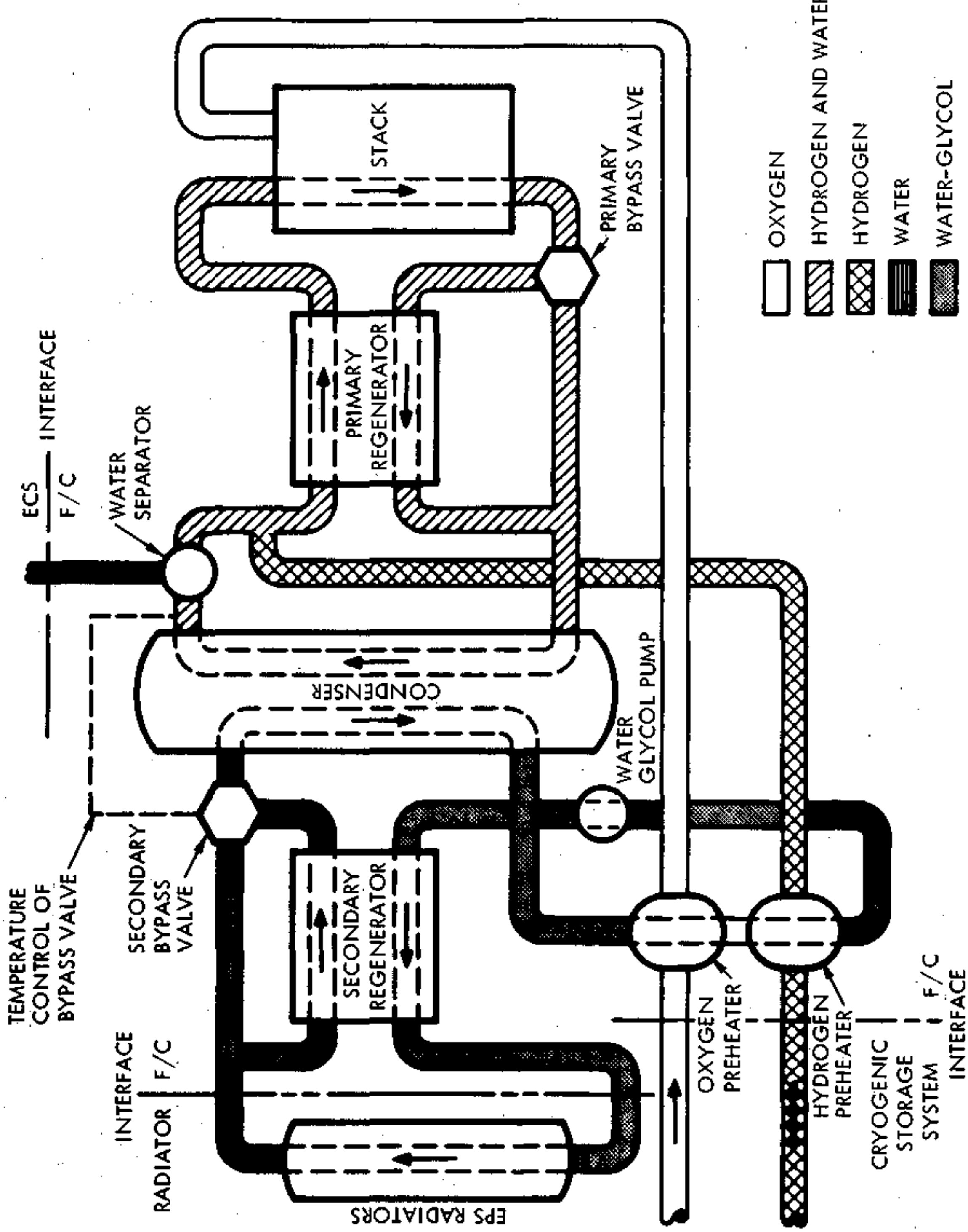


Figure 1. Fuel Cell Fluid and Component Schematic

A standard least squares surface fit bivariate polynomial routine was used in calculating the coefficients of this equation. The input data for the bivariate routine, as shown in Table 2, are the Reference 5 data corrected to a common KOH-water concentration of 0.75. The coefficients established from these data are given in Table 3. The resulting value, V_t, is corrected for the KOH-water concentration effect in the SINDA program by the following equation:

$$V = V_t - 0.241\ (0.75 - \mathrm{PCKOH}) \tag{3}$$

where

V = fuel cell voltage based on current, stack temperature, and KOH-water concentration (volts)

V_t = voltage based on current and stack temperature (volts)

PCKOH = the weight ratio of KOH to KOH + water

The value of V is used in the program as the fuel cell terminal voltage.

Table 2. Input Data for Bivariate Routine

Current (amperes)	Stack Temperature (°F)				
	380	400	420	440	460
15.0	30.0	30.8	31.4	31.8	31.9
20.0	29.1	30.0	30.6	31.0	31.3
25.0	28.3	29.2	29.9	30.4	30.7
30.0	27.5	28.5	29.4	29.8	30.1
35.0	26.7	27.8	28.8	29.2	29.6
40.0	26.0	27.2	28.2	28.7	29.0
45.0	25.3	26.5	27.6	28.2	28.5
50.0	24.6	25.9	27.0	27.7	28.1

Table 3. Output Coefficients From Bivariate Routine

A_1	5.583364	A_6	4.686233×10^{-3}
A_2	-1.308438	A_7	-3.573639×10^{-7}
A_3	2.054927×10^{-3}	A_8	-1.525995×10^{-5}
A_4	-1.333418×10^{-5}	A_9	-4.889387×10^{-6}
A_5	9.694690×10^{-2}	A_{10}	-1.292755×10^{-7}

Primary Loop Thermodynamics

Excess heat and steam produced in the chemical reaction in the stack are removed by the recirculating stream of hydrogen and water. The energy balance computation for the stack is based upon the total energy of reaction as input to the stack and the electrical power, stack temperature change, recirculating fluid temperature change, and fuel cell heat loss as output energy. The reaction energy is determined by

$$QGENAT = 51600. * SFCH2 \qquad (4)$$

where

QGENAT = reaction energy (Btu/hr)

SFCH2 = hydrogen consumption rate (lb/hr)

51600 Btu/lb is the lower heating value of hydrogen

The heat balance on the stack is given by

$$QSTORD = QGENAT - QH2 - QO2 - QELECT - QRS - QSM \qquad (5)$$

where

QSTORD = heat gained in the stack (Btu/hr)

QGENAT = reaction energy (Btu/hr)

QH2 = heat gained by the consumed hydrogen (Btu/hr)

QO2 = heat gained by the consumed oxygen (Btu/hr)

QELECT = electrical energy output (Btu/hr)

QRS = heat gained by the recirculating hydrogen-water stream (Btu/hr)

QSM = heat lost by the stack to the SM structure (Btu/hr)

A similar equation can be expressed for the primary loop heat balance:

$$QCOND = QGENAT - QELECT - QSM - QH2O \tag{6}$$

where

QCOND = heat transferred across the condenser (Btu/hr)

QH2O = energy in the condensed water above the 70 F datum (Btu/hr)

QGENAT, QELECT, and QSM are as previously defined.

After the two equations are balanced, the temperature can be determined in the primary loop by the following three equations:

$$TSE = TSTACK + (QSTORD*DTIMEU/30.) \tag{7}$$

where

TSE = the new stack temperature (°F)

TSTACK = the previous stack temperature (°F)

QSTORD = the stack heat gain (Btu/hr)

DTIMEU = the time step (hr)

30. = the stack mass-specific heat product (Btu/°F)

$$TSI = TSE - QSR/(WDTCPI + WDTCP2) \tag{8}$$

where

TSI = recirculating stream temperature at stack inlet (°F)

TSE = recirculating stream temperature at stack outlet (°F) (as well as the stack temperature)

3

QSR = heat gained by the recirculating hydrogen-water stream (Btu/hr)

WDTCP1 = the mass-specific heat product of the water in the recirculating stream

WDTCP2 = the mass-specific heat product of the hydrogen in the recirculating stream

$$TCIP = TCEP - (QCOND - CONST2)/(WDTCP1 + WDTCP2) \tag{9}$$

where

TCIP = recirculating stream temperature at condenser primary inlet (°F)

TCEP = recirculating stream temperature at condenser primary outlet (°F)

CONST2 = heat of vaporization of the condensed water

QCOND, WDTCP1, WDTCP2 are as previously defined.

The TCEP is determined in the condenser subroutine, which is described in the next section.

The mass balance in the primary loop is determined by assuming a constant volume delivery of 3 cfm at 60 psia for the primary pump for calculating the specific volume of the hydrogen and water at the stack inlet and outlet and at the condenser inlet and outlet. The partial pressure of water is first determined at the condenser exit, based upon the condenser exit temperature and a saturated steam condition. At the stack, the recirculating steam enters at this same condition and leaves at the temperature and the partial pressure of water in the electrolyte. Figure 2 illustrates the relationship of the electrolyte temperature, partial pressure of water, and KOH concentration. The program computes the equilibrium water pressure at the condition of electrolyte temperature and concentration at the beginning of the time step. This pressure is assumed to equal the partial pressure of water in the hydrogen-water stream at the stack exit at the end of the time step. Thus, the water balance is determined from the following equations:

$$WH2O2P = I*0.0230 * DTIMEU \tag{10}$$

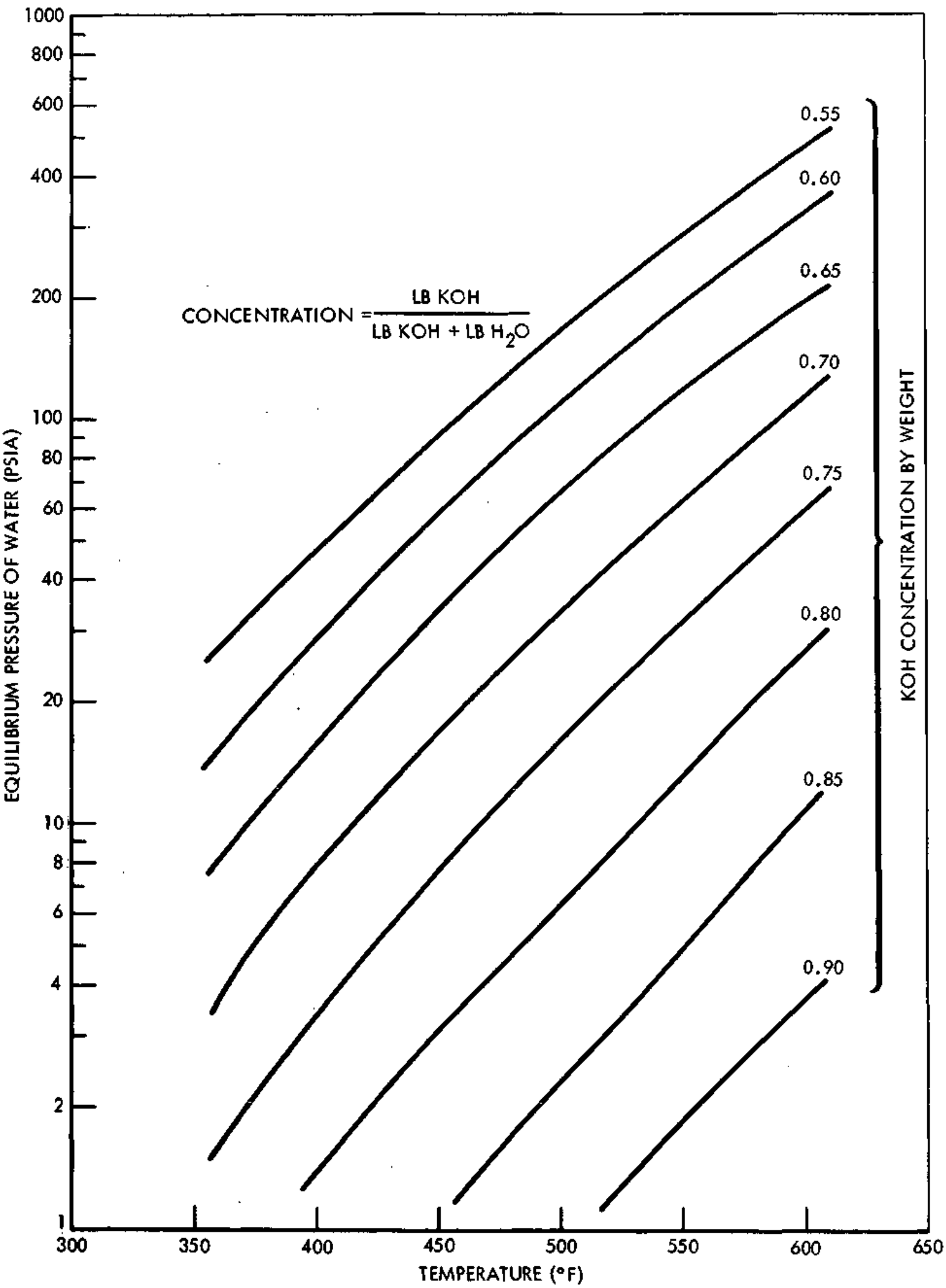


Figure 2. Water Pressure of KOH Electrolyte

where

WH202P = weight of water produced within the time step (lb)

I = current (amps)

DTIMEU = time step (hours)

0.0230 is the conversion factor for pounds of water produced per ampere-hour

$$WH2025 = WH2026 + WH202P * RATE \tag{11}$$

where

WH2025 = weight of water in the electrolyte at the end of the time step (lb)

WH2026 = weight of water in the electrolyte at the start of the time step (lb)

RATE = the percent of water produced during the time step that remains in the stack. RATE is calculated by an iterative balance between the water specific volume at the stack inlet and at the stack outlet and the water production rate.

$$PCKOH = 22.0/(22.0 + WH2025) \tag{12}$$

where

PCKOH = electrolyte concentration (ratio of KOH weight to total electrolyte weight)

KOH weight is 22.0 pounds

WH2025 is as previously defined

The mass balance of water at the condenser uses the specific volume of water determined at the stack outlet as the specific volume of water at the condenser inlet. The specific volume of water at the condenser outlet is determined by the condenser primary exit temperature, TCEP, and a saturated steam condition.

The amount of water condensed is found as follows:

$$DMASS = (180./SVOL11)*DTIMEU - (180./SVOL21)*DTIMEU \quad (13)$$

where

DMASS = water condensed (lb)

SVOL11 = specific volume of water at the condenser outlet (cu ft/lb)

SVOL12 = specific volume of water at the condenser inlet (cu ft/lb)

DTIMEU = time step (hours)

The mass balance for the reactants is based on providing the necessary flow to support the theoretical consumption rates without consideration of minor variations in regulated pressure:

$$SFCH2 = 8.292 * 10^{-5} * 31. * I \quad (14)$$

$$SFCO2 = 7.94 * SFCH2 \quad (15)$$

where

SFCH2 = hydrogen specific fuel consumption (lb/hr)

SFCO2 = oxygen specific fuel consumption (lb/hr)

The energy balance involving the consumed reactants is discussed in the Reactant Preheater section.

Condenser

The condenser is a counterflow heat exchanger interfacing the primary and secondary loops of the fuel cells. The condenser transfers the heat of the hydrogen-water mixture of the primary loop to the water-ethylene glycol mixture of the secondary loop. The normal operating range of the condenser exit temperature on the primary side (TCEP), which controls the secondary regenerator bypass valve, is 155 to 165 F.

Several schemes were considered for defining condenser performance. The method used, in view of simplicity of interface between the primary and secondary loops, was the balance of heat flow across the condenser. Data describing the condenser were obtained from Reference 6 and are provided in Figure 3 in the form of condenser performance curves. A multiple linear

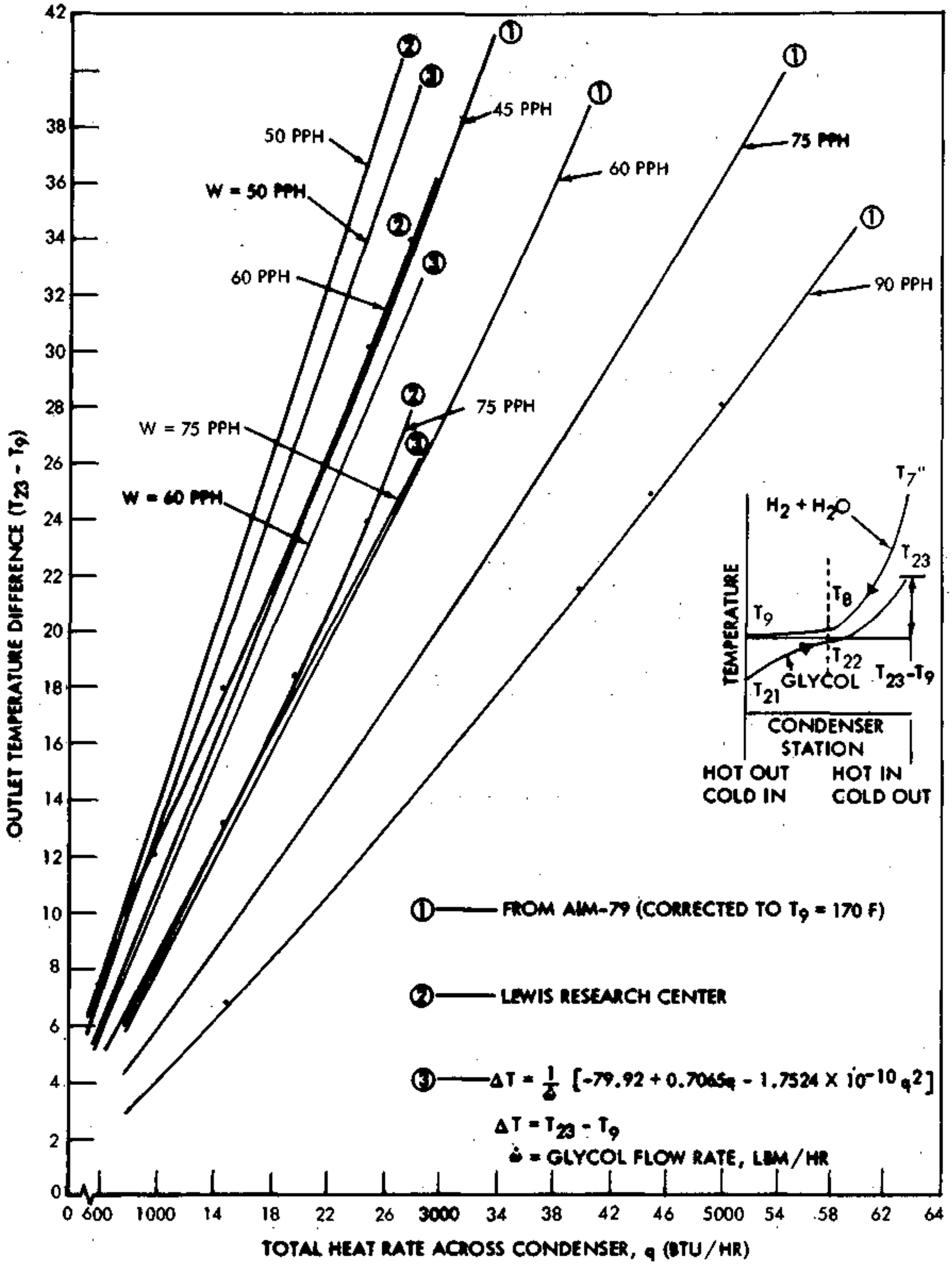


Figure 3. Condenser Performance Curves

regression scheme was then used to curve-fit the data. The following equation was obtained:

$$\text{TCEP-TCES} = (1./\text{WDWG})*(49.229 + 0.68747 * \text{QCOND} + 9.0145\text{E-7} * \text{QCOND} ** 2) \tag{16}$$

where

TCEP = condenser primary side exhaust temperature (°F)

TCES = condenser secondary side exhaust temperature (°F)

WDWG = water-glycol flow rate (lb/hr)

QCOND = heat flow across the condenser (Btu/hr)

The program makes successive approximations to balance the heat flow across the condenser. A value of QCOND is calculated from the primary loop parameters. Then the condenser glycol and gas exit temperatures are varied in accordance with Equation (16) until the heat lost to the glycol equals the QCOND calculated from the primary loop.

Secondary Regenerator and Bypass Valve Models

The secondary regenerator is modeled as a two-port network. The empirical relationships used for this model are typical for a counterflow heat exchanger and were taken from Reference 7. The hot outlet temperature, t_{h2}, can be written as

$$t_{h2} = (C_c/C_h)\ \epsilon(t_{c1} - t_{h1}) + t_{h1} \tag{17}$$

where

$C_c = W_c\ C_p(T)$

$C_h = W_h\ C_p(T)$

W_c, W_h = coolant flow rates on cold and hot sides (lb/hr)

$C_p(T)$ = coolant specific heat (a function of temperature)

ϵ = regenerator effectiveness

t_{c1} = cold side inlet temperature (°F)

t_{h1} = hot side inlet temperature (°F)

Figure 4 is a diagram of the regenerator with assigned terms.

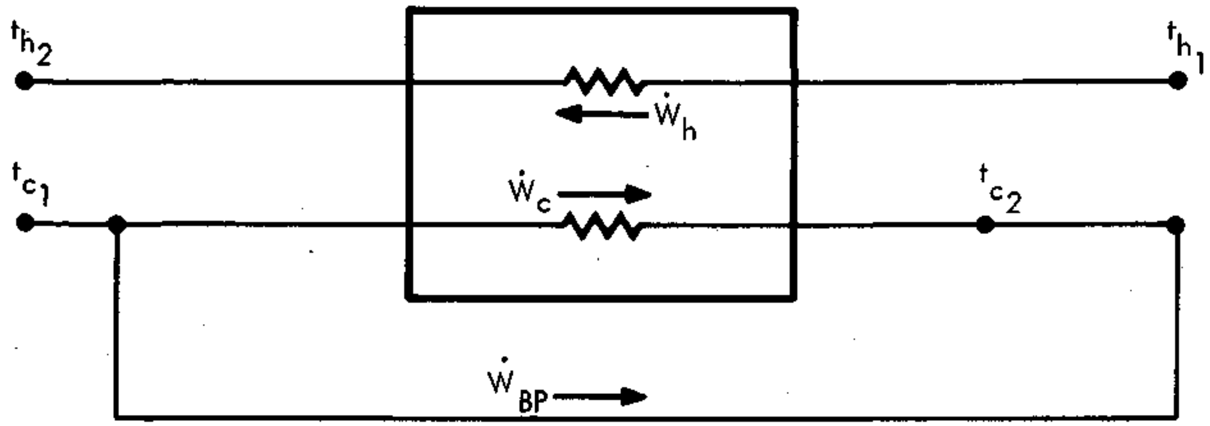


Figure 4. Secondary Regenerator Diagram

From Equation (17), the capacity ratio, C_c/C_h, can be rewritten as

$$C_c/C_h = \frac{\dot{W}_c \left(\frac{1}{t_{c_2} - t_{c_1}}\right) \int_{t_{c_1}}^{t_{c_2}} C_p\, dT}{\dot{W}_h \left(\frac{1}{t_{h_1} - t_{h_2}}\right) \int_{t_{h_2}}^{t_{h_1}} C_p\, dT} = \frac{\dot{W}_c\, \Delta T_h\, \Delta h_c}{\dot{W}_h\, \Delta T_c\, \Delta h_h} \qquad (18)$$

where

t_{c_2} = cold-side outlet temperature (°F)

ΔT = change in temperature (°F)

Δh = change in enthaply (Btu/lb)

Since the flow on the cold side of the regenerator is regulated by the secondary bypass valve, which is controlled by the primary condenser exit temperature, the portion of the cold-side flow that is bypassed must be considered. The relationship of the bypass flow rate, $\dot{W}_{BP}$, and the bypassed fraction, $\alpha = \dot{W}_{BP}/\dot{W}_h$, and the cold- and hot-side flow rates are given by the following equations:

$$\dot{W}_h = \dot{W}_c + \dot{W}_{BP} \qquad (19)$$

$$\dot{W}_c/\dot{W}_h = 1 - \alpha \qquad (20)$$

Equation (18) can then be rewritten by using the above expressions to give

$$C_c/C_h = (1 - \alpha) \frac{\Delta T_h \Delta h_c}{\Delta T_c \Delta h_h} = \beta \tag{21}$$

The parameters ϵ and β, together with the factor τ_{ij}, to represent the time response, define the relationship between the inlet and outlet temperatures of the regenerator:

$$\begin{bmatrix} t_{c_2} \\ t_{h_2} \end{bmatrix} = \begin{bmatrix} (1-\epsilon)\tau_{11} & \epsilon\,\tau_{12} \\ \epsilon\,\beta\tau_{21} & (1-\epsilon\beta)\tau_{22} \end{bmatrix} \begin{bmatrix} t_{c_1} \\ t_{h_1} \end{bmatrix} \tag{22}$$

This relation is solved in the program by a group of subroutines that update sliding arrays, move backward in the arrays to simulate delay, and perform integration. Figure 5 illustrates the relationship of the secondary regenerator cold-side inlet temperature to the regenerator effectiveness for various coolant flow rates. The data above an inlet of 70 degrees have been extrapolated.

The secondary bypass valve characteristics are shown in Figure 6. The program keeps track of the TCE in ascending or descending order and correspondingly interpolates on the correct curve.

Radiator System

The fuel cell and radiator system consists of eight 5-square-foot panels located on the CSM fairing. For the Skylab mission only two of the fuel cell and radiator coolant loops will be filled and connected for two-fuel-cell operation. While the radiator model discussion in this section is for the basic three-fuel-cell operational mode, two-fuel-cell operation for Skylab is simulated by using a zero flow pump characteristic for the third cell. For one-fuel-cell contingency operation, zero flow pump characteristics are used for two of the three cells. Reduced radiator area operation for low-power operation for Skylab missions is the same as for other Apollo missions: The bypass valve is actuated, and the last three panels are bypassed, and five-panel (five-eighths) radiator operation is achieved.

The original radiator model was included with the data deck for the CINDA program received from NASA (Reference 8). The model included a nodal network for each of the eight radiator panels and the coolant delivery and bypass lines. Figure 7 illustrates the nodal model that is typical for a single radiator panel. The solid and fluid node and conductor numbers shown in this figure represent panel 1 in the radiator system model. The corresponding node capacitance and conductor valves are given in Table 4. The

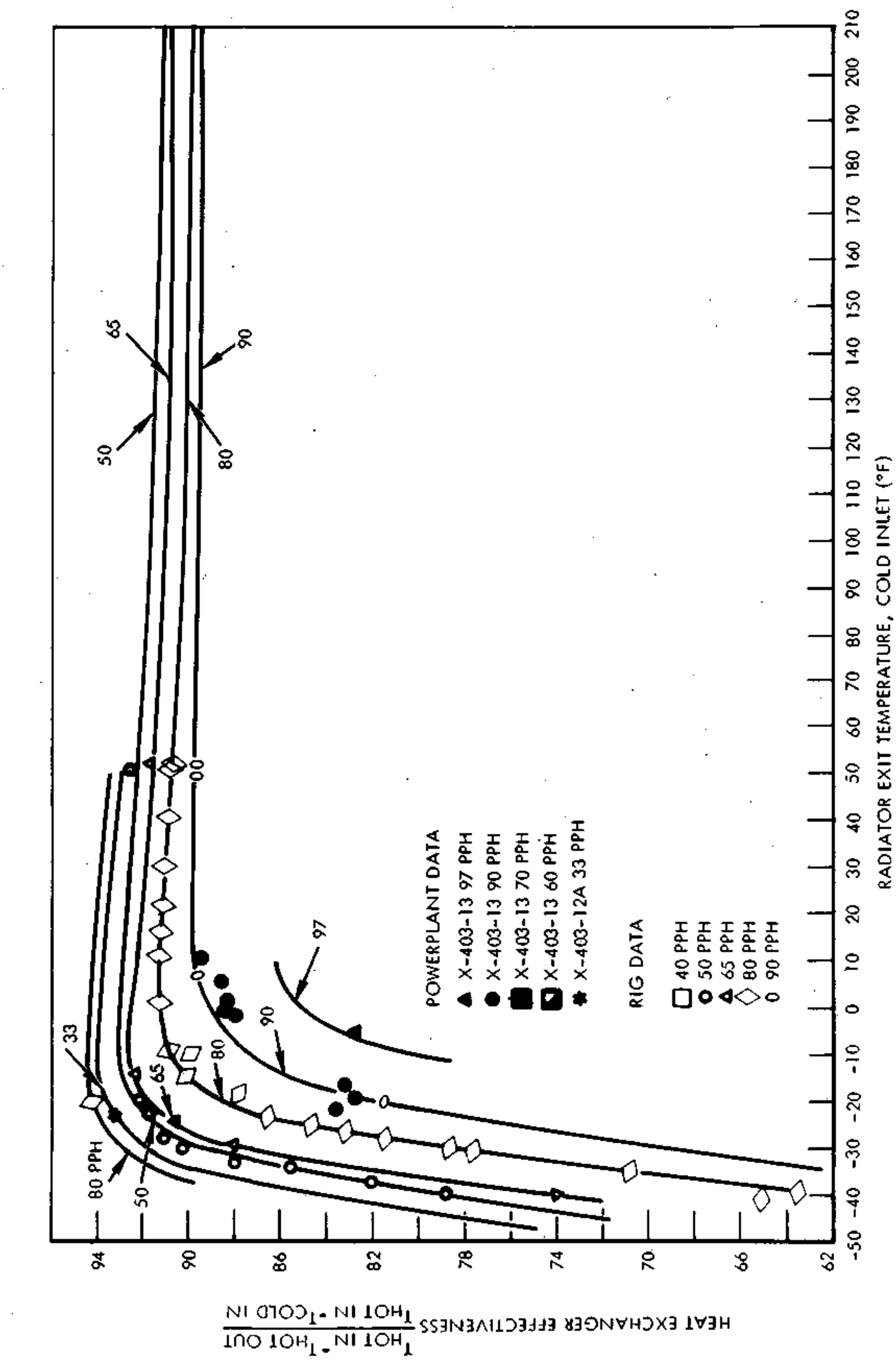


Figure 5. Secondary Regenerator Effectiveness

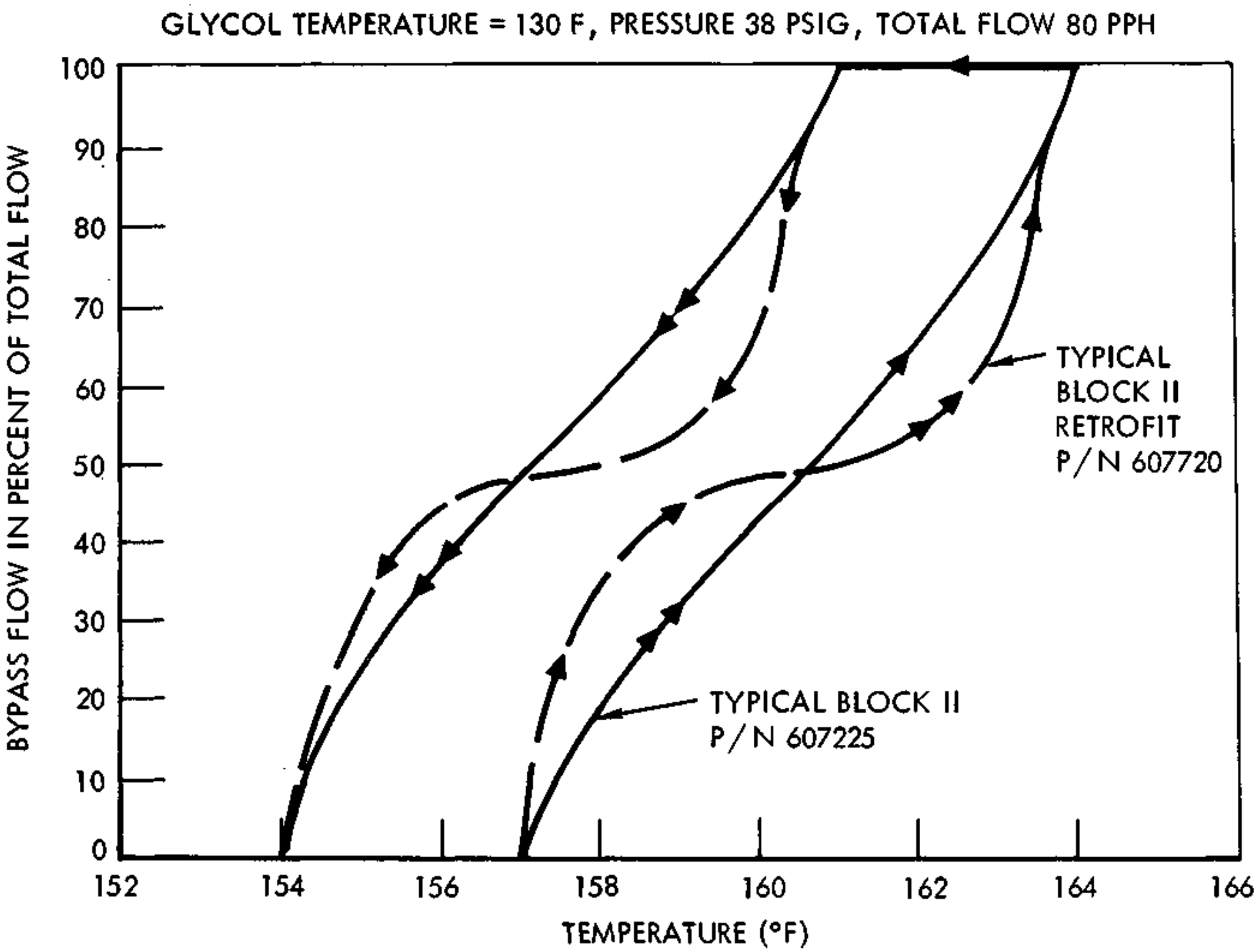


Figure 6. Secondary Bypass Valve Characteristics

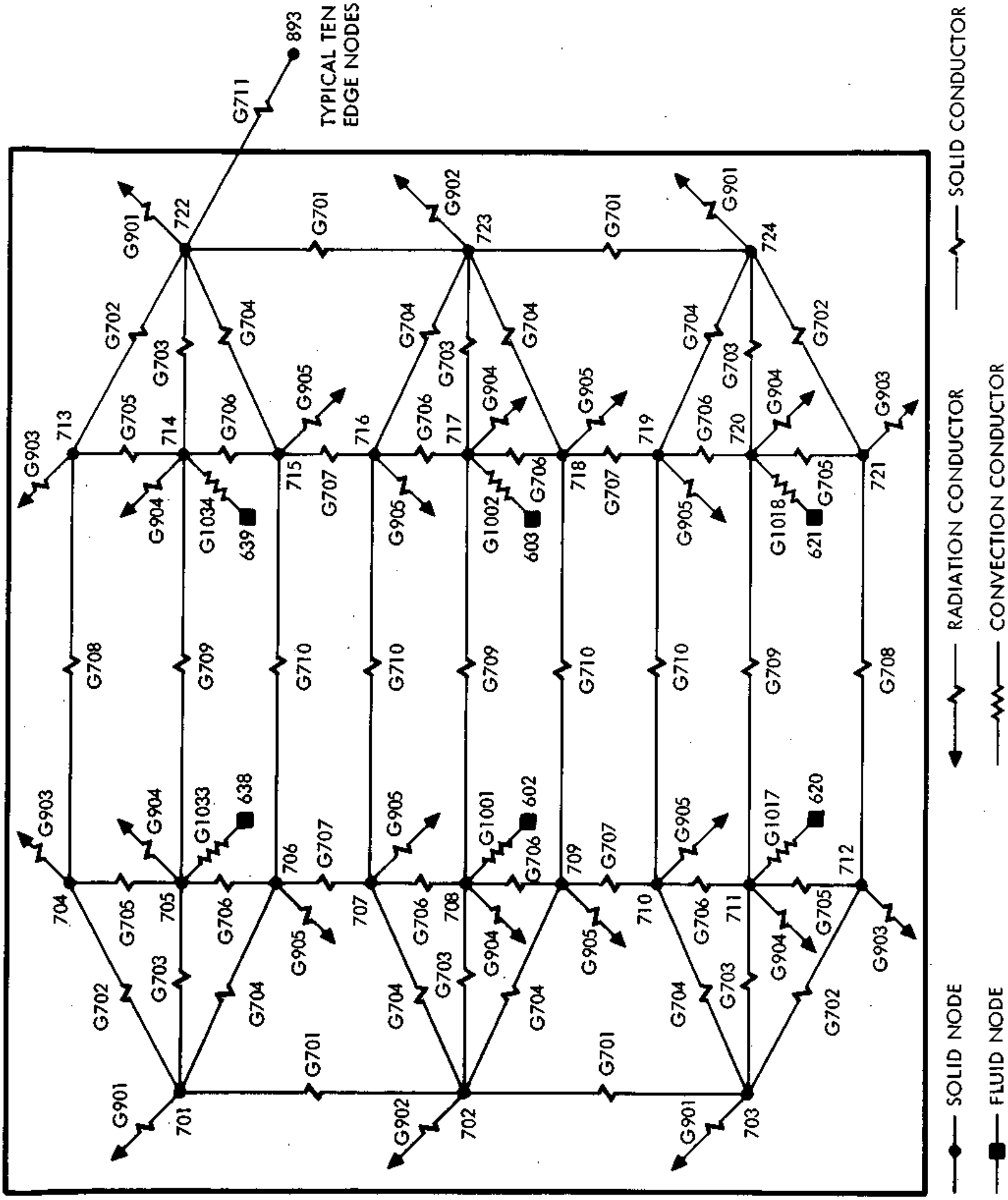


Figure 7. Typical Radiator Panel Nodal Network

Table 4. Capacitance and Conductance Values

Solid Node Number	Solid Node Capacitance $\rho C_p V$ (Btu/°F)
701	0.043269
702	0.037088
703	0.043269
704	0.098515
705	0.080002
706	0.067608
707	0.067608
708	0.080002
709	0.067608
710	0.067608
711	0.080002
712	0.098515
713	0.098515
714	0.080002
715	0.067608
716	0.067608
717	0.080002
718	0.067608
719	0.067608
720	0.080002
721	0.098515
722	0.043269
723	0.037088
724	0.043269
893	0.000000

Solid Conductor Number	Conductor Value KA/L (Btu/Hr °F)
701	0.199691
702	0.176766
703	0.090127
704	0.121294
705	3.111299
706	3.927239
707	3.422037
708	0.106059
709	0.182910
710	0.072776
711	0.010989

Radiation Conductor Number	Conductor Value $\sigma \epsilon FA$ (Btu/hr °F^4)
901	0.2298×10^{-9}
902	0.1970×10^{-9}
903	0.5234×10^{-9}
904	0.2700×10^{-9}
905	0.3591×10^{-9}

original values for the solid conductors were increased ten percent after it was found that the foil was two to three times thicker than required by the original specifications (Reference 9). Loss of heat through the radiator panel edges to the SM structure was accounted for by adding another solid node to the nodal network to represent the SM structure. Each of the solid-edge nodes of the eight radiator panels was tied to this SM structure node by a solid conductor. A structure temperature within a ±150 F range and an infinite capacitance is assigned the structure node, depending upon the environment being simulated.

The fuel cell/radiator coolant is a water-ethylene glycol solution composed of 62.5 percent ethylene glycol by weight. The coolant properties used in the analysis as functions of temperature are density (Figure 8); conductivity (Figure 9); specific heat (Figure 10); viscosity (Figure 11); and relative enthalpy (Figure 12). The coolant pump characteristic, flow versus pressure drop in the radiator loop, is shown as Figure 13. The pressure drop in the radiator loop is calculated by using the Fanning equation with a dynamic head loss factor in the subroutine (Reference 8).

Reactant Preheaters

In the secondary loop, the water-glycol, after exiting from the condenser, flows through the reactant preheaters before passing into the secondary regenerator. The basic equations simulating the reactant preheaters were taken from Reference 10, with corrections made to preserve compatibility with the secondary loop model.

The effectivity of the oxygen preheater is shown in Figure 14 and expressed as

$$EFF = 0.53 + 0.002 * WDWG + 0.018 * WDO2 \qquad (23)$$

where

EFF = effectivity

WDWG = water-glycol flow rate (lb/hr)

WDO2 = oxygen flow rate (lb/hr)

The oxygen preheater outlet temperature can then be found from Equations (23) and (24):

$$TO2O = TO2I + (TWGOI-TO2I) * EFF \qquad (24)$$

where

TO2O = oxygen outlet temperature (°R)

TO2I = oxygen inlet temperature assumed constant = 530°R

TWGOI = water-glycol temperature at condenser outlet (°R)

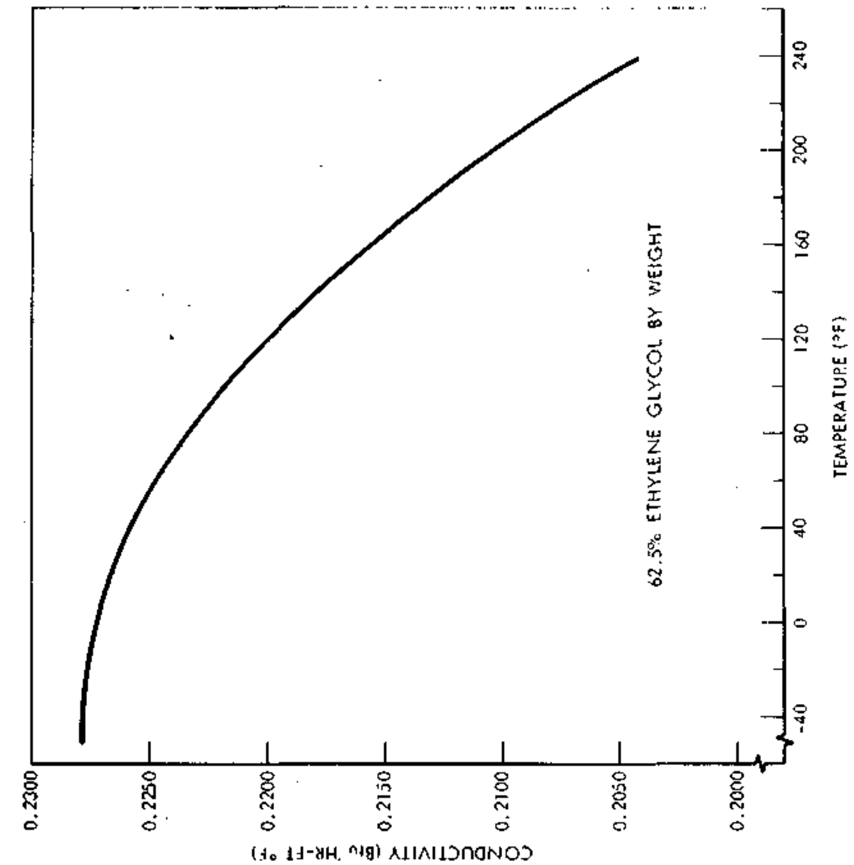


Figure 9. Conductivity of Water-Glycol Mixture

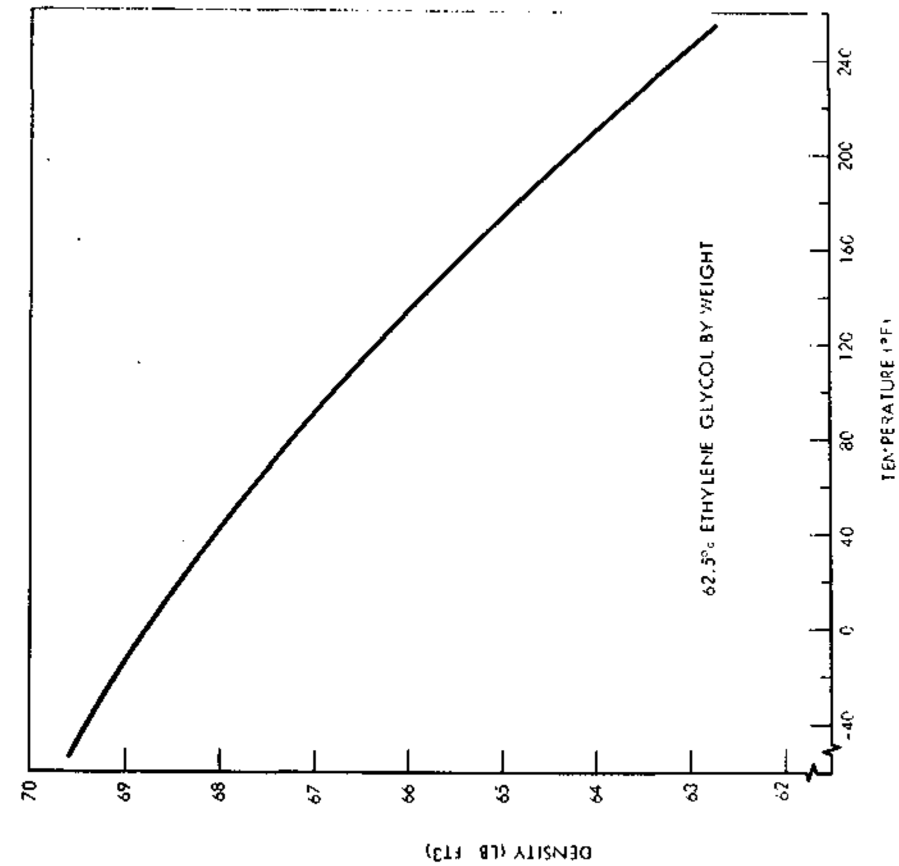


Figure 8. Density of Water-Glycol Mixture

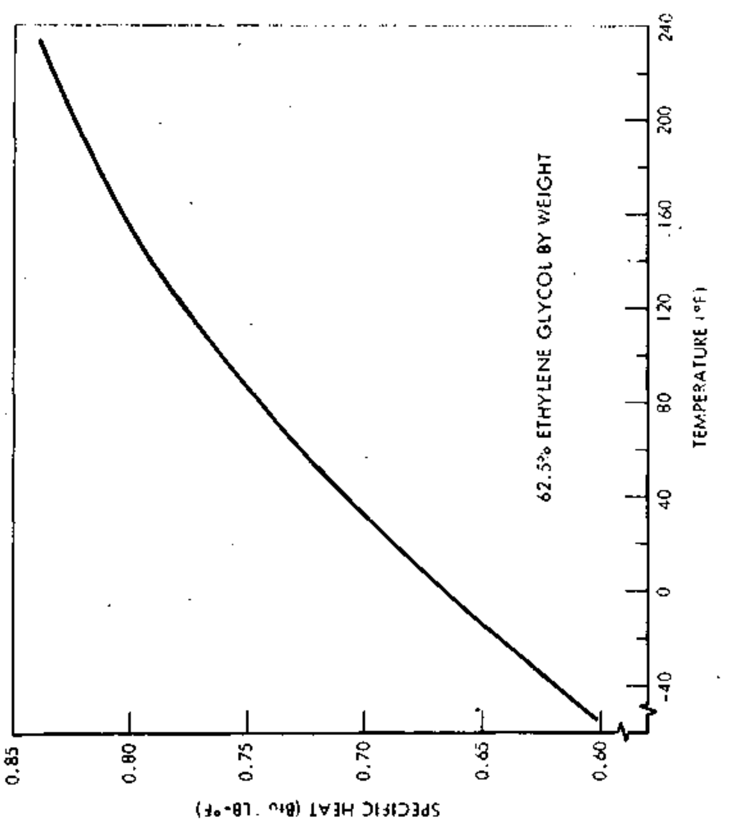


Figure 10. Specific Heat of Water-Glycol Mixture

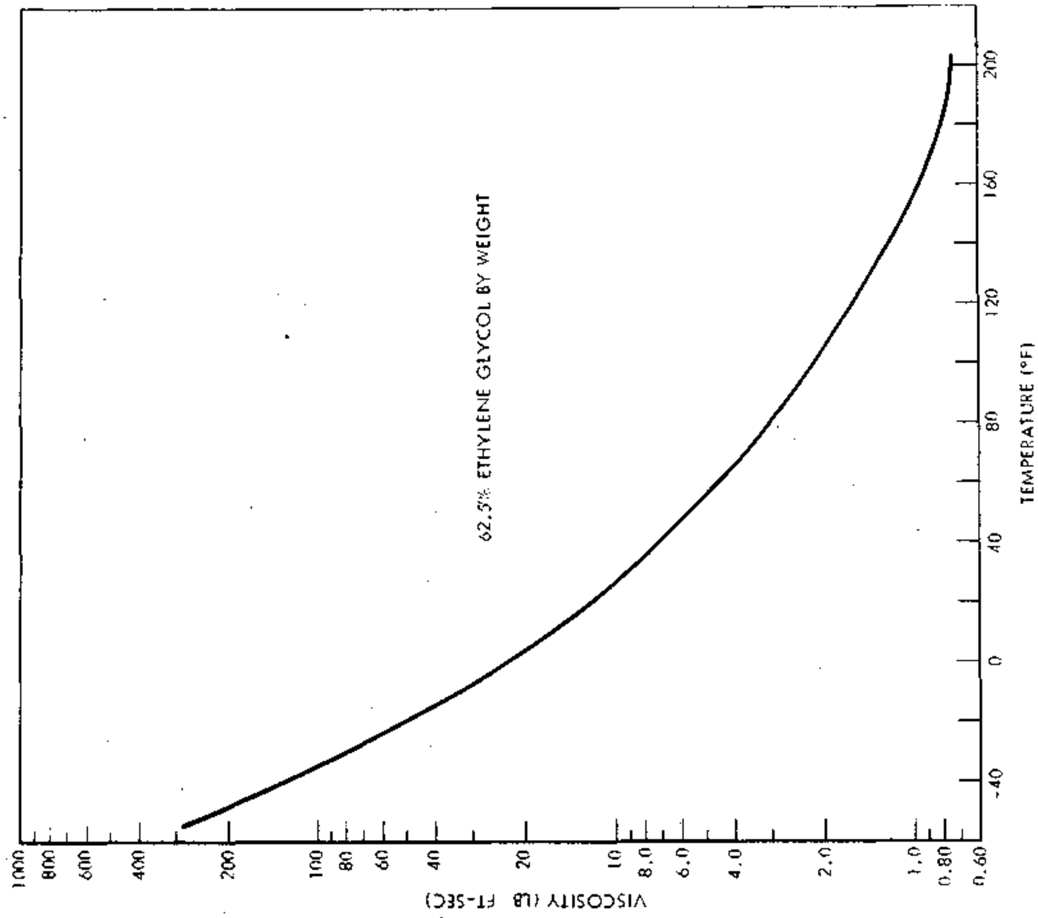


Figure 11. Viscosity of Water-Glycol Mixture

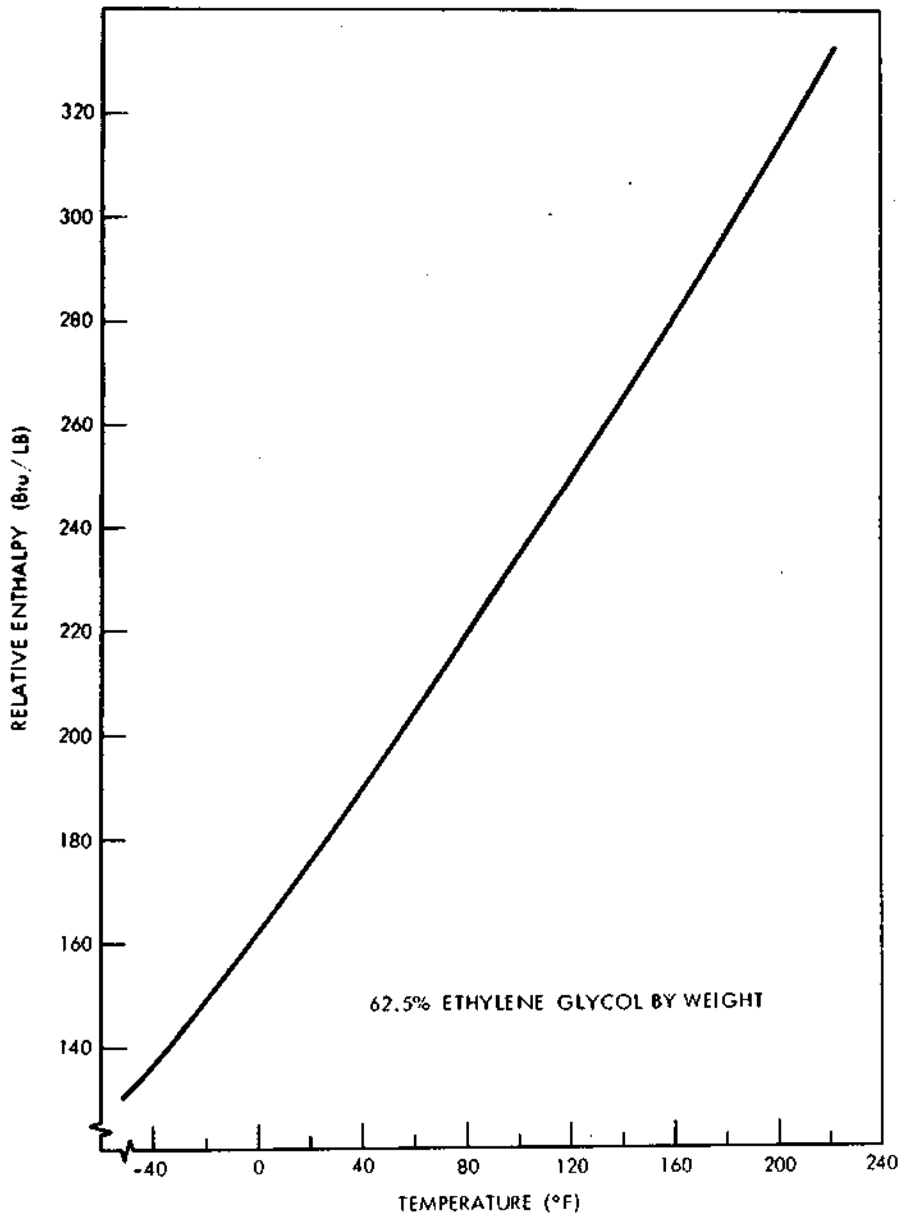


Figure 12. Relative Enthalpy of Water-Glycol Mixture

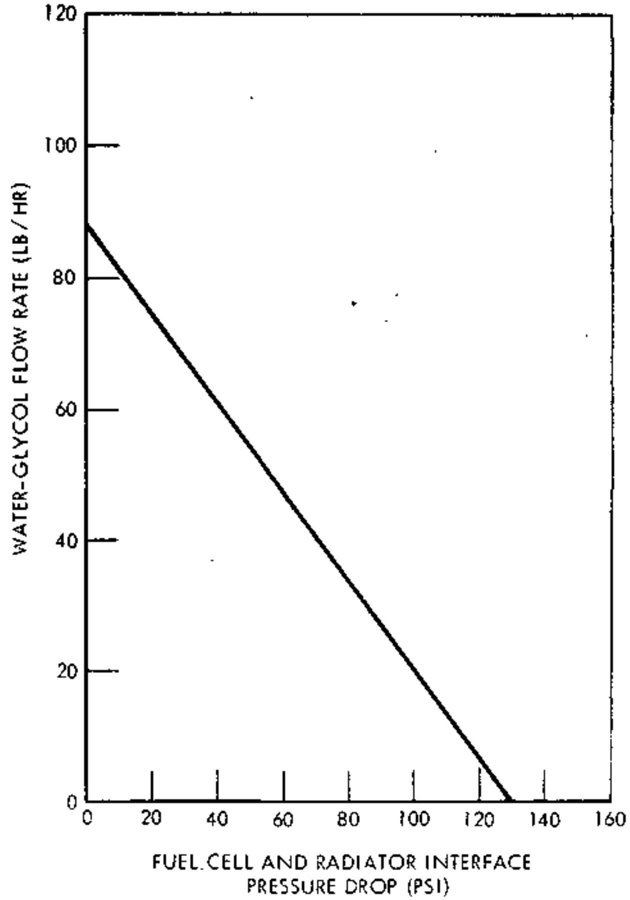
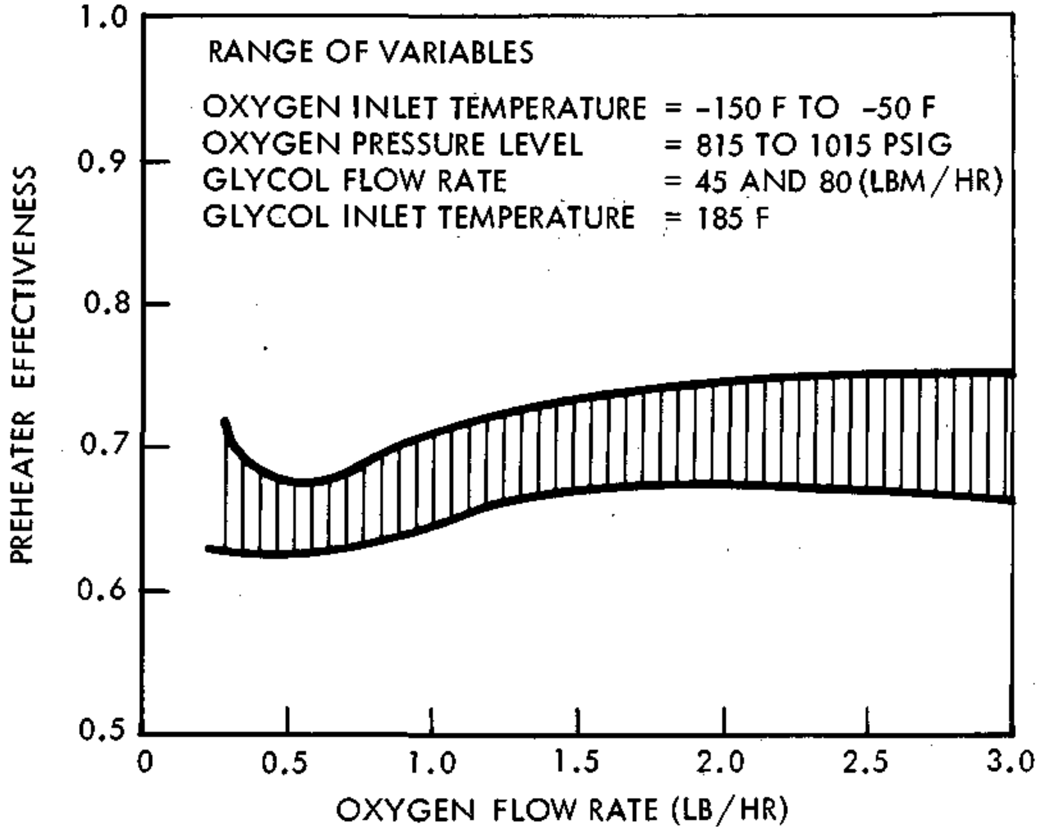


Figure 13. Water-Glycol Pump Characteristic



(FROM P&WA MONTHLY PROGRESS REPORT, PWA - 2345, 25 MAY 1964)

Figure 14. Oxygen Preheater Effectiveness

From Equation (25), the change in enthalpy of the water-glycol flowing through the oxygen preheater can be obtained:

$$DHO2 = (TO2I-TO2O)*(0.152+0.0000225*(TO2O+TO2I))*WDO2/WDWG \tag{25}$$

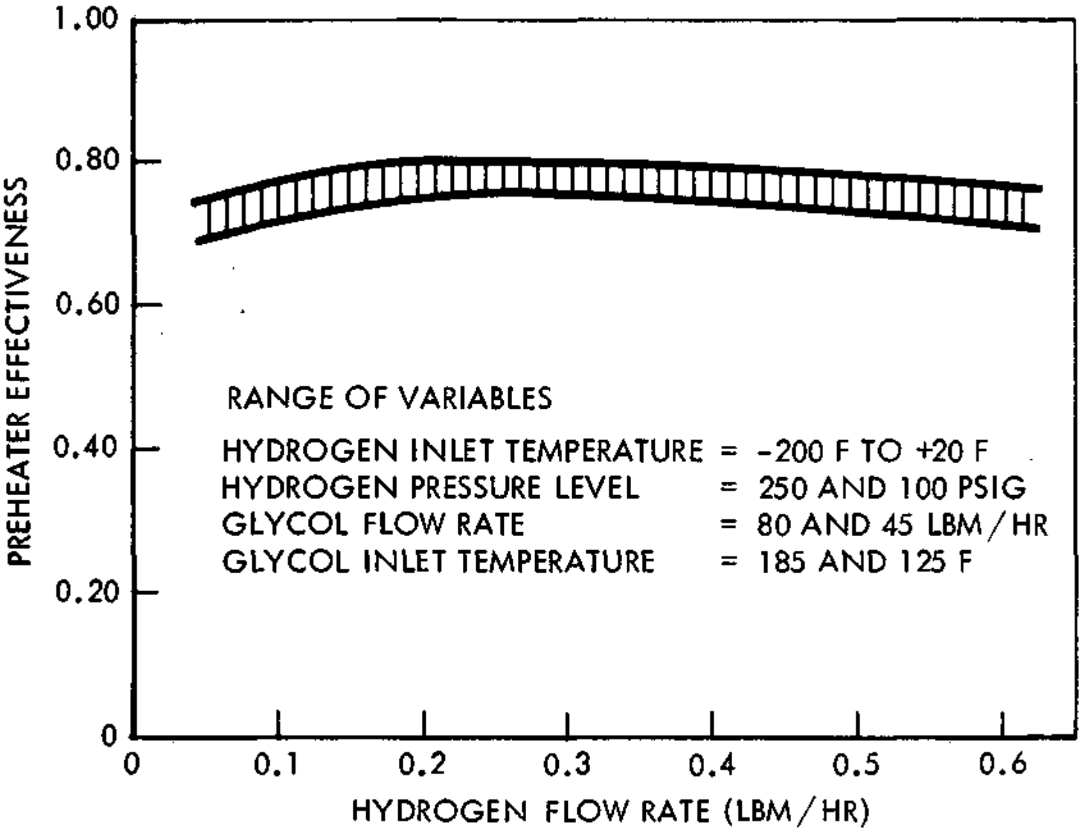
where

DHO2 = enthalpy change of the water-glycol through the oxygen preheater (Btu/lb)

The temperature of the water-glycol (TWGHI) exiting the oxygen preheater is found from the change in enthalpy and preheater water-glycol inlet temperature.

The effectivity of the hydrogen preheater is assumed constant at 0.75 (Figure 15). Equation (26) is similar to Equation (24) and gives the hydrogen preheater outlet temperature:

$$TH2O = TH2I + 0.75 * (TWGHI-TH2I) \tag{26}$$



(FROM P&WA MONTHLY PROGRESS REPORT, PWA - 2332, 27 APRIL 1964)

Figure 15. Hydrogen Preheater Effectiveness

where

TH2O = hydrogen outlet temperature (°R)

TH2I = hydrogen inlet temperature, assumed constant = 530°R

TWGHI = water-glycol temperature at hydrogen preheater inlet (°R)

The enthalpy change of the water-glycol flowing through the hydrogen preheater is then

$$DHH2 = (TH2I-TH2O) * 3.47 * WDH2/WDWG \tag{27}$$

where

WDH2 = hydrogen flow rate (lb/hr)

DHH2 = enthalpy change in the water-glycol through the hydrogen preheater (Btu/lb)

The temperature of the water-glycol exiting the hydrogen preheater can then be found from the enthalpy change and the water-glycol temperature

entering the preheater. The water-glycol exit temperature is taken as the inlet temperature of the hot side of the secondary regenerator.

Fuel Cell Heat Loss to Structure

The fuel cell heat loss to the SM structure is based upon information given in Reference 5. The data as shown in Reference 5 are plots of fuel cell heat loss as a function of stack temperature for three parametric structure temperatures: 30, 80 and 130 F. These data were replaced with the following linear equation, which is used in the SINDA fuel cell model:

$$QSM = 3.25 * TS - 1.6 * TA - 882. \qquad (28)$$

where

QSM = fuel cell heat loss to structure (Btu/hr per cell)

TS = fuel cell stack temperature (°F)

TA = ambient structure temperature (°F)

The ambient temperature is assigned as an independent parameter, based upon space environmental conditions. A temperature of 30 F is selected for extreme cold conditions; 130 F for extreme hot conditions, and 80 F for nominal conditions. There is no attempt to determine the direct heat conduction through the fuel cell cone mount nor to determine the heat radiation from the pressure jacket and accessory package components. The program does not attempt to determine the changes in the ambient structure temperature resulting from such heating. The equation is accurate to within ±4 percent of the data from Reference 5.

4.2 PROGRAM DEFINITION

The CINDA-3G (Chrysler Improved Numerical Differencing Analyzer for Third-Generation Computers) computer program was developed by the Thermodynamics Section of the Aerospace Physics Branch of the Chrysler Corporation Space Division at the National Aeronautics and Space Administration's Michoud Assembly Facility. The CINDA-3G program, written to run on the Univac 1108, was converted by the Computer Science Branch of the Idaho Nuclear Corporation to run on the IBM 360/75 computer. The converted program, called SINDA-3G (Systems instead of Chrysler), provides a variety of methods for the solution of thermal analog models presented in a network format. The network representation is unique in that it has a one-to-one correspondence to both the physical model and the mathematical model. The program allows the models to be developed through use of combinations of FORTRAN statements, user-initiated subroutines, and the numerous subroutines contained within the program. These program subroutines can be used for handling interrelated complex phenomena such as

sublimation; diffuse radiation within enclosures; simultaneous, one-dimensional, incompressible, fluid flow, including valving and transport delay effects; and similar areas associated with heat transfer and fluid flow.

In the hands of a competent engineering analyst, the SINDA-3G program is a powerful tool for analyzing thermal systems.

4.3 MODEL AND PROGRAM INPUT

Data Deck Setup

A SINDA-3G program deck contains two main blocks: a data block and an operations block. Each block is subdivided into four blocks. The four data blocks are entitled the NODE DATA, CONDUCTOR DATA, CONSTANTS DATA, and ARRAY DATA. The four operations blocks are designated EXECUTION, VARIABLES 1, VARIABLES 2, and OUTPUT CALLS.

Card columns 12 through 80 comprise the data field. The instruction field (operations blocks) consists of columns 12 through 72. The program processes the problem data into FORTRAN common data and converts instructions into FORTRAN source language. They are then passed on to the system FORTRAN compiler. Instruction cards containing an F in column 1 are passed on exactly as received. Discussion of the operations blocks will follow discussion of the data blocks.

Data input to the data blocks may be one or more integers, floating numbers (with or without the E exponent designation), or alphanumeric words of up to six characters each. The reading of a word or number continues until a comma is encountered. Then the next word or number is read. Words or numbers may not be broken between cards, and a new card is equivalent to starting with a comma. Therefore, no continuation designation is required. When sequential commas are encountered, the program places floating-point zero values between them. Reading continues until the terminal column is reached or a dollar sign is encountered. Comments for a data card can be placed after a dollar sign and are not processed by the program.

The first card in each of the four data blocks must be started in column 8 with the mnemonic code BCD (binary coded decimal), then an integer (1 through 9) in column 12, and the name of the data block starting in column 13. Each data block must be terminated with a mnemonic END card.

The NODE DATA block contains the data describing all nodes in the network. Each set of node data is grouped similar to the following code:

```
column 12
         N#, Ti, Ca
```

where

N# = integer node number
Ti = initial node temperature
Ca = node capacitance

All nodes are numbered by the program sequentially (from 1 on) in the order received. The user input number is designated the actual node number. The program assigned number is termed the relative node number.

Second in the group of data blocks is the CONDUCTOR DATA block. In the nodal network, nodes are joined together with conductors. The three types of conductors used in the SINDA-3G program are conduction (solid), convection, and radiation conductors. Conductors are input to the program with the code.

```
column 12
         G#, NA, NB, Cn
```

where

G# = integer conductor number
NA = one adjoining node number
NB = the other adjoining node number
Cn = conductance value

If more than one conductor has the same constant value, they may share the same conductor number and value. This is accomplished by placing two or more pairs of integer-adjoining node numbers between the conductor number and value.

The data for the CONSTANTS DATA block are always input as doublets, the constant name or number followed by its value. They are divided into two types, control constants and user constants, and may be intermingled within the block. User constants receive a number. Control constants have alphanumeric names.

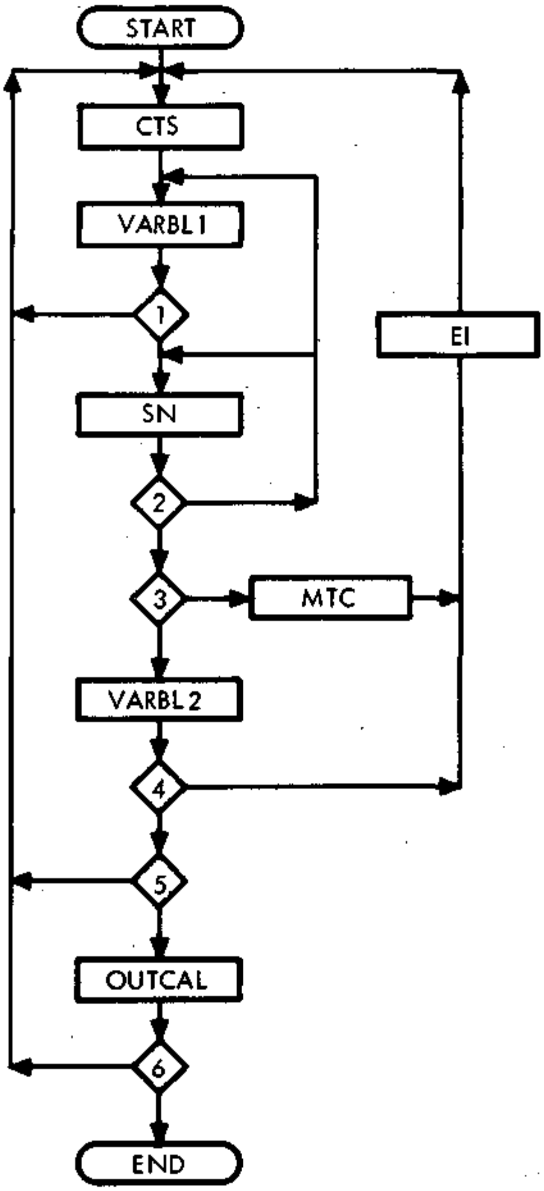
The ARRAY DATA block is the last of the four data blocks. Input of data into this block is exceedingly simple. The array number is listed, followed by the sequential listing of the data, and terminated with an END (data END, not mnemonic). The interpolation and matrix subroutines of the program make extensive use of these arrays. The SPACE option in the ARRAY DATA block is an easy way for the user to specify a large number of locations, which are initialized by the preprocessor program as floating-point zeros. When this option is used, the array number is listed, followed by the word SPACE and the number of locations to be initialized, and terminated with an END.

While the four data blocks provide the data for the program, the four operations blocks determine the program control. This they do through the use of various operations and instructions. The four operations blocks, EXECUTION, VARIABLES 1, VARIABLES 2, and OUTPUT CALLS, are preprocessed by the SINDA-3G program and passed on to the system FORTRAN compiler as four separate subroutines entitled EXECTN, VARBL1, VARBL2, and OUTCAL, respectively. Figure 16 illustrates the basic flow diagram for the solution of the network.

When the FORTRAN compilation is successfully completed, control is passed to the EXECTN subroutine. It sequentially performs the operations in the same order as input by the user in the EXECUTION block. None of the operations specified in the other three blocks is performed unless it is called for either directly by name in the EXECUTION block or internally by some other called for subroutine. All operations and instructions listed in EXECUTION block and performed by the program are executed only once. Because of this feature, the EXECTN subroutine can be used to initialize constants and variables, fabricate new arrays, establish steady-state parameters, and perform other operations that are completed only once during the duration of the program.

The operations in the VARIABLES 1 block can be considered pre-solution operations. These operations may include construction of temperature arrays, establishment of heating rates, calculation of heating sources, or other basic operations required for solution of the thermal nodal network.

In the same respect, the VARIABLES 2 block operations may be thought of as post-solution operations. VARIABLES 2 allows the user to look at the recently solved network. Typical operations of the VARBL2 subroutine may include integration of flow rates, corrections of empirical relationships to reflect thermal solution of the nodal network, updating of conductances to account for changes in node temperatures, etc.



OPERATION	DESCRIPTION
CTS	CALCULATE TIME STEP
VARBL 1	VARIABLES 1 OPERATIONS
SN	SOLVE NETWORK
VARBL 2	VARIABLES 2 OPERATIONS
OUTCAL	OUTPUT CALLS OPERATIONS
MTC	MODIFY TIME CONTROL
EI	ERASE ITERATION

CHECK	REVERSE DIRECTION IF
1	BACKUP NONZERO
2	RELAXATION CRITERIA NOT MET
3	TIME OR TEMP CHANGE TOO LARGE
4	BACKUP NONZERO
5	NOT TIME TO PRINT
6	PROBLEM STOP TIME NOT REACHED

Figure 16. Basic Flow Chart for Network Solution Subroutines

The operations in the OUTPUT CALLS block are performed on the output interval specified by the user in the program. Since the operations are performed only at the output interval, OUTPUT CALLS typically contains only instructions for outputting information.

The aforementioned data and operations blocks constitute a SINDA-3G program data deck. The deck must be terminated with the following card:

column	8	12
	BCD	3END OF DATA

The user has the option to use the subroutines contained in the SINDA-3G library or to write his own. When non-SINDA-3G subroutines are being called, the data communication is obtained through subroutine arguments similar to any other subroutine.

Sample Problem Input Data

The listing of the sample input data is included in the appendix. The data are presented in the same order as stated in the Data Deck Setup section: the node data first, followed by the conductor data and constants data, and concluded with the array data.

The node data includes the solid temperature nodes for the eight radiator panels, the water-glycol fluid temperature nodes for the three-fuel-cell system, the fluid pressure nodes, and the edge sink and environmental sink nodes for the eight panels.

The 11 solid (conduction) conductors are the first of the data listed in the conductor data. Next are the convection conductors and the pressure and fluid flow conductors for the three systems. The conductor data are concluded with the five radiation conductors.

The constants data contain the 472 constants used in the program. These constants are listed by their actual number rather than the program-assigned relative numbers.

Listed in the last section of the problem input data are the array data. Eighty-four arrays are listed, with most arrays containing data and the remaining arrays using the SPACE option to allocate program storage locations.

Following the input data is a listing of the main program (EXECTN, VARBL1, VARBL2, and OUTCAL) and the 12 user-written subroutines.

Sample Problem Output

Figure 17 illustrates a typical problem output listing. The listing is headed with the title "Systems Improved Numerical Differencing Analyzer * SINDA * North American Rockwell Corporation - Space Division" and followed by 11 output interval data sets. Each output interval data set is started with four asterisks. The first data line contains five control constants with their values listed to the right of each constant. The last three constants have the relative node number enclosed in parentheses. The control constants are:

TIME	Present mission time (hr)
DTIMEU	Last time step used for transient network problem (hr)
CSGMIN	Most recent minimum stability criteria for the network
DTMPCC	Maximum diffusion temperature change calculated over the last time step
ARLXCC	Maximum arithmetic relaxation change calculated over the last iteration

The next four lines of output are associated with the primary loop operation. The first two lines list the titles, with the values following. The titles are defined as follows:

SYSTEM	Fuel cell system in operation (for Skylab configuration only two fuel cell systems are used, systems 1 and 3)
POWER	Fuel cell power output (watts)
CURRENT	Fuel cell output current (amps)
VOLTAGE	Fuel cell output voltage (volts)
TSI	Stack inlet temperature (°F)
TSE	Stack exit temperature (°F)
TCIP	Condenser inlet temperature, primary loop (°F)
TCEP	Condenser exit temperature, primary loop (°F)
QCOND	Heat flow across the condenser (Btu/hr)

W-COND	Weight rate of water condensed (lb/hr)
WS-RATE	Percent of water produced in the time interval that remains in the stack (%)
TO2	Oxygen reactant temperature at stack inlet (°F)
TH2	Hydrogen reactant temperature before mixing with the primary recirculation stream (°F)
PCKOH	Electrolyte concentration ratio

Secondary loop operations are listed in the next four lines, with the titles followed by their values. The titles represent:

FLOW RATE	Water glycol flow rate (lb/hr)
QRAD	Heat flow across the radiators (Btu/hr)
TRADIN	Temperature of the radiator inlet (°F)
TRADOUT	Temperature of the radiator outlet (°F)
DPRAD	Pressure drop through the radiator loop (psi)
TSRCI	Temperature of the secondary regenerator at the cold-side inlet (°F)
TSRCE	Temperature of the secondary regenerator at the cold-side exit (°F)
TSRHI	Temperature of the secondary regenerator at the hot-side inlet (°F)
TSRHE	Temperature of the secondary regenerator at the hot-side exit (°F)
TCIS	Condenser inlet temperature, secondary loop (°F)
TCES	Condenser exit temperature, secondary loop (°F)
BPFS	Bypassed ratio at the secondary regenerator

The final data group lists the radiator inlet and outlet temperature for the eight radiator panels for all three systems. The temperatures are listed in degrees Fahrenheit. The four asterisks following this data group designate the start of a new output interval data set.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Space Division
North American Rockwell

SYSTEMS IMPROVED NUMERICAL DIFFERENCING ANALYZER * SINDA * NORTH AMERICAN ROCKWELL CORPORATION - SPACE DIVISION PAGE 2

* * * *
TIME 5.49999E-01 DTIMEU 1.67292E-03 CSGMIN(8) 3.06978E-03 DTMPCC(152) 1.12518E-01 ARLXCC(196) 1.40869E-01

SYSTEM	POWER WATTS	CURRENT AMPS	VOLTAGE VOLTS	TSI DEGF	TSE DEGF	TCIP DEGF	TCEP DEGF	QCOND BTU/HR	W-COND LB/HR	WS-RATE PERCENT	TO2 DEGF	TH2 DEGF	PCKOH
1	1303.97	45.00	28.98	357.50	437.05	234.16	135.62	2931.22	1.466	-41.60	133.78	137.48	0.735
3	1303.97	45.00	28.98	357.50	437.05	234.18	135.65	2930.12	1.465	-41.54	133.80	137.51	0.735

SYSTEM	FLOW RATE LB/HR	QRAD BTU/HR	TRADIN DEGF	TRADOUT DEGF	DPRAD PSI	TSRCI DEGF	TSRCE DEGF	TSRHI DEGF	TSRHE DEGF	TCIS DEGF	TCES DEGF	BPFS
1	84.66	824.69	84.20	71.08	5.055	71.22	116.23	159.77	84.11	116.23	160.06	0.0
3	84.62	819.52	84.57	71.53	5.128	71.66	116.26	159.81	84.47	116.26	160.10	0.0

PANEL 1 IN	PANEL 1 OUT	PANEL 2 IN	PANEL 2 OUT	PANEL 3 IN	PANEL 3 OUT	PANEL 4 IN	PANEL 4 OUT	PANEL 5 IN	PANEL 5 OUT	PANEL 6 IN	PANEL 6 OUT	PANEL 7 IN	PANEL 7 OUT	PANEL 8 IN	PANEL 8 OUT
83.8	83.4	82.8	82.2	80.4	78.7	77.0	75.4	74.5	73.7	73.0	72.2	71.6	71.0	71.0	71.1
69.4	69.0	55.4	54.5	47.0	44.4	28.5	26.8	39.5	38.3	57.5	56.3	50.1	49.5	67.4	67.3
84.2	84.0	83.0	82.2	80.4	78.7	77.5	76.3	75.1	73.9	73.1	72.4	71.9	71.5	71.5	71.5

* * * *
TIME 5.99999E-01 DTIMEU 1.66243E-03 CSGMIN(8) 3.07111E-03 DTMPCC(152) 9.87169E-02 ARLXCC(196) 1.24390E-01

SYSTEM	POWER WATTS	CURRENT AMPS	VOLTAGE VOLTS	TSI DEGF	TSE DEGF	TCIP DEGF	TCEP DEGF	QCOND BTU/HR	W-COND LB/HR	WS-RATE PERCENT	TO2 DEGF	TH2 DEGF	
1	1305.09	45.00	29.00	357.19	437.49	234.69	135.40	2939.13	1.465	-41.59	133.70	137.43	0.735
3	1305.08	45.00	29.00	357.19	437.49	234.71	135.44	2937.78	1.465	-41.51	133.72	137.45	0.735

Figure 17. Sample Problem Output

4.4 ANALYTICAL RESULTS

Three temperature levels are monitored to determine if the fuel cells are operating within the specified limits. These temperatures are measured at the condenser primary exit, the radiator exit, and the stack. The nominal condenser primary exit temperature range is 155 to 165 F, with allowable cycling to 200 F. The caution and warning (C&W) alarms for the condenser exit are set for 150 F and 175 F. For the analysis, the acceptable minimum power operation was defined for condenser operation as between 150 and 155 F. The acceptable maximum power operation was defined as between 165 and 200 F. The stack and radiator exit temperatures are less limiting than the condenser exit temperature. This is evidenced by results in which seven of the eight cases reached the condenser exit limits. The remaining case was limited by the stack temperature.

The nominal stack temperature range is 390 to 460 F, with the C&W alarms at 360 F and 475 F. For the analysis, the acceptable minimum stack temperature range was 360 to 390 F. The maximum was defined as 460 to 475 F. The radiator exit-temperature nominal range is 0 to 120 F, with allowable high-temperature cycling to 180 F. The C&W alarm is set only for the minimum temperature condition of -30 F. Only the acceptable minimum radiator temperature range was defined for the analysis. This range, -30 to 0 F, was not encountered in any of the eight cases.

Two environmental heating profiles were used for the heat that is radiated to radiator panels. The hotter environment, which was used for the maximum power cases, has a β angle of 73.5 degrees for a circular earth orbit of 235 nautical miles with the vehicle in a Z-local vertical attitude hold. The colder environment for the minimum power cases uses a β angle of 0 degrees for the same orbit and attitude conditions.

The power levels shown in Tables 1, 5 and 6 represent the expected power requirements for the Skylab missions. One-fuel-cell operation and five-eighths radiator area are contingency operation modes that are considered irreversible. That is, once the contingency mode is selected, a return to normal two-fuel-cell or full-area operation is never required.

With the exception of Case 2, the power levels shown in Table 5 can be raised slightly by operation at the condenser C&W limit of 175 F. Operation to 200 F is acceptable for peak cycling conditions. However, once the nominal bypass limit of 165 F is exceeded, a slight increase in power results in a significant temperature rise. Case 3, one fuel cell, full area at 60 amperes, is the only case where the stack temperature limits the power. In this case, a greater increase in power is available if operated to the stack temperature C&W limit of 475 F.

For all of the minimum power cases listed in Table 6, slightly lower power capability is possible by operating down to the condenser C&W limit of 150 F. The temperatures shown in Tables 5 and 6 are orbital extremes except where differences occurred between fuel cells in two-fuel-cell operation. Then the value shown is the average between the two cells at the orbital extreme condition.

Table 5. System Temperatures for High Power Levels

Case	β Angle (deg)	Number of Fuel Cells in Operation	Radiator Area (operating panels)	Total Fuel Cell Current Level (amps)	System Temperatures (°F)			
					Condenser Exit	Stack	Radiator Inlet	Radiator Outlet
1	73.5	2	8	100.	168.45	455.93	189.87	150.58
2	73.5	2	5	90.	192.01	452.11	208.98	178.48
3	73.5	1	8	60.	163.77	470.24	190.24	138.04
4	73.5	1	5	50.	172.98	458.70	194.06	155.91

Table 6. System Temperatures for Low Power Levels

Case	β Angle (deg)	Number of Fuel Cells in Operation	Radiator Area (operating panels)	Total Fuel Cell Current Level (amps)	System Temperatures (°F)			
					Condenser Exit	Stack	Radiator Inlet	Radiator Outlet
5	0.	2	8	50.	154.30	418.25	52.85	33.03
6	0.	2	5	40.	151.46	412.36	66.11	49.82
7	0.	1	8	30.	155.06	426.05	47.12	19.08
8	0.	1	5	25.	153.41	419.54	46.71	24.57

5. REFERENCES

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2. EPS Radiator Thermal Vacuum Environment Qualification Test Block II. North American Rockwell Space Division, SID 66-1909 (1 March 1967).

3. Notes and Write-ups of IBM 360/75 version of SINDA-3G computer program, from K. R. Katsma, Idaho Nuclear Corporation, Idaho Falls, Idaho.

4. Thompson, R. A., and G. A. Swanson and R. H. Shaw. Fuel Cell System Thermodynamic Analysis. Pratt and Whitney Aircraft, Division of United Aircraft, East Hartford, Connecticut (18 December 1961).

5. CSM/LM Spacecraft Operation Data Book, Volume 1. North American Rockwell Space Division, SD 68-447-1A, Revision 2 (24 September 1969).

6. Weinstein, M. B. Apollo Fuel-Cell Condenser Heat Transfer Tests. NASA Lewis Research Center (123-34-02-01-22, 1966).

7. Giedt, Warren H. Principles of Engineering Heat Transfer. New York: D. Van Nostrand Company, Inc. (1957).

8. Personal communication from Harry J. Cazemier. "Development of a Thermal Analog Model of the Block II Electrical Power System Radiators for the Chrysler Improved Numerical Differencing Analyzer (CINDA) Computer Program," NASA Manned Spacecraft Center, Houston, Texas (February 1969).

9. "EPS CINDA Radiator Model," IL 695-202-110-69-099 by G. A. Vanderpol. North American Rockwell Space Division (23 October 1969).

10. Simulation of the Apollo Applications CSM Electrical Power System. North American Rockwell Space Division, SD 69-269 (December 1969).

APPENDIX: INPUT DATA, MAIN PROGRAM LISTING, AND USER SUBROUTINE LISTINGS

INPUT DATA

PRECEDING PAGE BLANK NOT FILMED

```
BCD 3THERMAL SPCS                                                       $TTL0010
END
BCD 3NODE DATA                                                          $NODO010
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 1)                          $NODO020
     701,100.,.0432693,702,100.,.0370880,703,100.,.0432693              $NODO030
     704,100.,.0985149,705,100.,.0800018,706,100.,.0676083              $NODO040
     707,100.,.0676083,708,100.,.0800018,709,100.,.0676083              $NODO050
     710,100.,.0676083,711,100.,.0800018,712,100.,.0985149              $NODO060
     713,100.,.0985149,714,100.,.0800018,715,100.,.0676083              $NODO070
     716,100.,.0676083,717,100.,.0800018,718,100.,.0676083              $NODO080
     719,100.,.0676083,720,100.,.0800018,721,100.,.0985149              $NODO090
     722,100.,.0432693,723,100.,.0370880,724,1[illegible]0.,.0432[illegible]          $NODO100
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 2)                          $NODO110
     725,100.,.0432693,726,100.,.0370880,727,100.,.0432693              $NODO120
     728,100.,.0985149,729,100.,.0800018,730,100.,.0676083              $NODO130
     731,100.,.0676083,732,100.,.0800018,733,100.,.0676083              $NODO140
     734,100.,.0676083,735,100.,.0800018,736,100.,.0985149              $NODO150
     737,100.,.0985149,738,100.,.0800018,739,100.,.0676083              $NODO160
     740,100.,.0676083,741,100.,.0800018,742,100.,.0676083              $NODO170
     743,100.,.0676083,744,100.,.0800018,745,100.,.0985149              $NODO180
     746,100.,.0432693,747,100.,.0370880,748,100.,.0432693              $NODO190
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 3)                          $NODO200
     749,100.,.0432693,750,100.,.0370880,751,100.,.0432693              $NODO210
     752,100.,.0985149,753,100.,.0800018,754,100.,.0676083              $NODO220
     755,100.,.0676083,756,100.,.0800018,757,100.,.0676083              $NODO230
     758,100.,.0676083,759,100.,.0800018,760,100.,.0985149              $NODO240
     761,100.,.0985149,762,100.,.0800018,763,100.,.0676083              $NODO250
     764,100.,.0676083,765,100.,.0800018,766,100.,.0676083              $NODO260
     767,100.,.0676083,768,100.,.0800018,769,100.,.0985149              $NODO270
     770,100.,.0432693,771,100.,.0370880,772,100.,.0432693              $NODO280
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 4)                          $NODO290
     773,100.,.0432693,774,100.,.0370880,775,100.,.0432693              $NODO300
     776,100.,.0985149,777,100.,.0800018,778,100.,.0676083              $NODO310
     779,100.,.0676083,780,100.,.0800019,781,100.,.0676083              $NODO320
     782,100.,.0676083,783,100.,.0800018,784,100.,.0985149              $NODO330
     785,100.,.0985149,786,100.,.0800018,787,100.,.0676083              $NODO340
     788,100.,.0676083,789,100.,.0800018,790,100.,.0676083              $NODO350
     791,100.,.0676083,792,100.,.0800018,793,100.,.0985149              $NODO360
     794,100.,.0432693,795,100.,.0370880,796,100.,.0432693              $NODO370
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 5)                          $NODO380
     797,100.,.0432693,798,100.,.0370880,799,100.,.0432693              $NODO390
     800,100.,.0985149,801,100.,.0800018,802,100.,.0676083              $NODO400
     803,100.,.0676083,804,100.,.0800018,805,100.,.0676083              $NODO410
     806,100.,.0676083,807,100.,.0800018,808,100.,.0985149              $NODO420
     809,100.,.0[illegible],8[illegible],10[illegible].,.0[illegible]18,811,100.,.067[illegible]    [illegible]NODO430
     812,100.,.0676083,813,100.,.0800018,814,100.,.[illegible]         $NODO440
     815,100.,.0676083,816,100.,.0800018,817,100.,.0985149              $NODO450
     818,100.,.0432693,819,100.,.0370880,820,100.,.0432693              $NODO460
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 6)                          $NODO470
     821,100.,.0432693,822,100.,.0370880,823,100.,.0432693              $NODO480
     824,100.,.0985149,825,100.,.0800018,826,100.,.0676083              $NODO490
     827,100.,.0676083,828,100.,.0800018,829,100.,.0676083              $NODO500
     830,100.,.0676083,831,100.,.0800018,832,100.,.0985149              $NODO510
     833,100.,.0985149,834,100.,.0800018,835,100.,.0676083              $NODO520
     836,100.,.0676083,837,100.,.0800019,838,100.,.0676083              $NODO530
     839,100.,.0676083,840,100.,.0800018,841,100.,.0985149              $NODO540
     842,100.,.0432693,843,100.,.0370880,844,100.,.0432693              $NODO550
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REM RADIATOR SOLID TEMPERATURE NODES (PANEL 7)                              $NOD0560
      845,100.,.0432693,846,100.,.0370880,847,100.,.0432693                 $NOD0570
      848,100.,.0985149,849,100.,.0800018,850,100.,.0676083                 $NOD0580
      851,100.,.0676083,852,100.,.0800018,853,100.,.0676083                 $NOD0590
      854,100.,.0676083,855,100.,.0800018,856,100.,.0985149                 $NOD0600
      857,100.,.0985149,858,100.,.0800018,859,100.,.0676083                 $NOD0610
      860,100.,.0676083,861,100.,.0800018,862,100.,.0676083                 $NOD0620
      863,100.,.0676083,864,100.,.0800018,865,100.,.0985149                 $NOD0630
      866,100.,.0432693,867,100.,.0370880,868,100.,.0432693                 $NOD0640
REM RADIATOR SOLID TEMPERATURE NODES (PANEL 8)                              $NOD0650
      869,100.,.0432693,870,100.,.0370880,871,100.,.0432693                 $NOD0660
      872,100.,.0985149,873,100.,.0800018,874,100.,.0676083                 $NOD0670
      875,100.,.0676083,876,100.,.0800018,877,100.,.0676083                 $NOD0680
      878,100.,.0676083,879,100.,.0800018,880,100.,.0985149                 $NOD0690
      881,100.,.0985149,882,100.,.0800018,883,100.,.0676083                 $NOD0700
      884,100.,.0676083,885,100.,.0800018,886,100.,.0676083                 $NOD0710
      887,100.,.0676083,888,100.,.0800018,889,100.,.0985149                 $NOD0720
      890,100.,.0432693,891,100.,.0370880,892,100.,.0432693                 $NOD0730
REM FLUID TEMPERATURE ARITHMETIC NODES                                      $NOD0750
     617,116.,-1.,616,119.,-1.,615,119.,-1.,614,122.,-1.
     613,122.,-1.,612,125.,-1.,611,125.,-1.,610,128.,-1.
     609,128.,-1.,608,131.,-1.,607,131.,-1.,606,134.,-1.
     605,134.,-1.,604,137.,-1.,603,137.,-1.,602,140.,-1.
     635,116.,-1.,634,119.,-1.,633,119.,-1.,632,122.,-1.
     631,122.,-1.,630,125.,-1.,629,125.,-1.,628,128.,-1.
     627,128.,-1.,626,131.,-1.,625,131.,-1.,624,134.,-1.
     623,134.,-1.,622,137.,-1.,621,137.,-1.,620,140.,-1.
     653,116.,-1.,652,119.,-1.,651,119.,-1.,650,122.,-1.
     649,122.,-1.,648,125.,-1.,647,125.,-1.,646,128.,-1.
     645,128.,-1.,644,131.,-1.,643,131.,-1.,642,134.,-1.
     641,134.,-1.,640,137.,-1.,639,137.,-1.,638,140.,-1.
REM FLUID TEMPERATURE NODES - MIXING (SYSTEMS 1,2,3)                        $NOD0880
     618,116.,-1.,636,116.,-1.,654,116.,-1.
REM FLUID TEMPERATURE NODES - BOUNDARY (SYSTEMS 1,2,3)                      $NOD0900
     -601,190.,,-619,190.,,-637,190.,                                       $NOD0910
REM FLUID PRESSURE NODES (SYSTEM 1)                                         $NOD0920
     -501,,,-502,,,-503,,,-504,,,-505,,,-506,,,-507,,,-508,,                $NOD0930
     -509,,,-510,,,-511,,,-512,,,-513,,,-514,,,-515,,,-516,,                $NOD0940
     -517,,,-518,,,-519,,,-520,,,-521,,,-522,,,-523,,,-524,,                $NOD0950
     -525,,,-526,,,-527,0.                                                  $NOD0960
REM FLUID PRESSURE NODES (SYSTEM 2)                                         $NOD0970
     -528,,,-529,,,-530,,,-531,,,-532,,,-533,,,-534,,,-535,,                $NOD0980
     -536,,,-537,,,-538,,,-539,,,-540,,,-541,,,-542,,,-543,,                $NOD0990
     -544,,,-545,,,-546,,,-547,,,-548,,,-549,,,-550,,,-551,,                $NOD1000
     -552,,,-553,,,-554,0.                                                  $NOD1010
REM FLUID PRESSURE NODES (SYSTEM 3)                                         $NOD1020
     -555,,,-556,,,-557,,,-558,,,-559,,,-560,,,-561,,,-562,,                $NOD1030
     -563,,,-564,,,-565,,,-566,,,-567,,,-568,,,-569,,,-570,,                $NOD1040
     -571,,,-572,,,-573,,,-574,,,-575,,,-576,,,-577,,,-578,,                $NOD1050
     -579,,,-580,,,-581,0.                                                  $NOD1060
REM EDGE SINK TEMPERATURE NODE FOR PANELS 1 TO 8
      -893,-150.,
REM ENVIRONMENTAL SINK TEMPERATURE NODES FOR PANELS 1 TO 8                  $NOD1070
      -901,-460.,,-902,-460.,,-903,-460.,,-904,-460.,,-905,-460.,           $NOD1080
      -906,-460.,,-907,-460.,,-908,-460.,                                   $NOD1090
END                                                                         $NOD1110
BCD 3CONDUCTOR DATA                                                         $CND0010
REM                                                                         $CND0020
REM                                                                         $CND0030
REM SOLID CONDUCTOR - NUMBER 701                                            $CND0040
REM                                                                         $CND0050
      701,701,702,702,703,722,723,723,724        $PANEL 1                   $CND0060
      725,726,726,727,746,747,747,748            $PANEL 2                   $CND0070
      749,750,750,751,770,771,771,772            $PANEL 3                   $CND0080
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      773,774,774,775,794,795,795,796          $PANEL 4            $CND0090
      797,798,798,799,818,819,819,820          $PANEL 5            $CND0100
      821,822,822,823,842,843,843,844          $PANEL 6            $CND0110
      845,846,846,847,866,867,867,868          $PANEL 7            $CND0120
     869,870,870,871,890,891,891,892,.1996911 $PANEL 8            $CND0130
REM SOLID CONDUCTOR - NUMBER 702                                   $CND0140
      702,701,704,703,712,713,722,721,724      $PANEL 1            $CND0150
      725,728,727,736,737,746,745,748          $PANEL 2            $CND0160
      749,752,751,760,761,770,769,772          $PANEL 3            $CND0170
      773,776,775,784,785,794,793,796          $PANEL 4            $CND0180
      797,800,799,809,809,818,817,820          $PANEL 5            $CND0190
      821,824,823,832,833,842,841,844          $PANEL 6            $CND0200
      845,848,847,856,857,866,865,868          $PANEL 7            $CND0210
     869,872,871,880,881,890,889,892,.1767663 $PANEL 8            $CND0220
REM SOLID CONDUCTOR - NUMBER 703                                   $CND0230
      703,701,705,702,708,703,711,714,722,717,723,720,724     $PNL1$CND0240
      725,729,726,732,727,735,738,746,741,747,744,748         $PNL2$CND0250
      749,753,750,756,751,759,762,770,765,771,768,772         $PNL3$CND0260
      773,777,774,780,775,783,786,794,789,795,792,796         $PNL4$CND0270
      797,801,798,804,799,807,810,818,813,819,816,820         $PNL5$CND0280
      821,825,822,828,823,831,834,842,837,843,840,844         $PNL6$CND0290
      845,849,846,852,847,855,858,866,861,867,864,868         $PNL7$CND0300
     869,873,870,876,871,879,882,890,885,891,888,892,.090127 $PNL8$CND0310
REM SOLID CONDUCTOR - NUMBER 704                                   $CND0320
      704,701,706,702,707,702,709,703,710    $ PANEL 1            $CND0330
      715,722,716,723,718,723,719,724        $ PANEL 1            $CND0340
      725,730,726,731,726,733,727,734        $ PANEL 2            $CND0350
      739,746,740,747,742,747,743,748        $ PANEL 2            $CND0360
      749,754,750,755,750,757,751,758        $ PANEL 3            $CND0370
      763,770,764,771,766,771,767,772        $ PANEL 3            $CND0380
      773,778,774,779,774,781,775,782        $ PANEL 4            $CND0390
      787,794,788,795,790,795,791,796        $ PANEL 4            $CND0400
      797,802,798,803,798,805,799,806        $ PANEL 5            $CND0410
      811,818,812,819,814,819,815,820        $ PANEL 5            $CND0420
      821,826,822,827,822,829,823,830        $ PANEL 6            $CND0430
      835,842,836,843,838,843,839,844        $ PANEL 6            $CND0440
      845,850,846,851,846,853,847,854        $ PANEL 7            $CND0450
      859,866,860,867,862,867,863,868        $ PANEL 7            $CND0460
      869,874,870,875,870,877,871,878        $ PANEL 8            $CND0470
     883,890,884,891,886,891,887,892,.121294 $ PANEL 8            $CND0480
REM SOLID CONDUCTOR - NUMBER 705                                   $CND0490
      705,704,705,711,712,713,714,720,721      $PANEL 1            $CND0500
      728,729,735,736,737,738,744,745          $PANEL 2            $CND0510
      752,753,759,760,761,762,768,769          $PANEL 3            $CND0520
      776,777,783,784,785,786,792,793          $PANEL 4            $CND0530
      800,801,807,808,809,810,816,817          $PANEL 5            $CND0540
      824,825,831,832,833,834,840,841          $PANEL 6            $CND0550
      848,849,855,856,857,858,864,865          $PANEL 7            $CND0560
     872,873,879,880,881,882,888,889,3.111299  $PANEL 8            $CND0570
REM SOLID CONDUCTOR - NUMBER 706                                   $CND0580
      706,705,706,707,708,708,709,710,711      $PANEL 1            $CND0590
      714,715,716,717,717,718,719,720          $PANEL 1            $CND0600
      729,730,731,732,732,733,734,735          $PANEL 2            $CND0610
      738,739,740,741,741,742,743,744          $PANEL 2            $CND0620
      753,754,755,756,756,757,758,759          $PANEL 3            $CND0630
      762,763,764,765,765,766,767,768          $PANEL 3            $CND0640
      777,778,779,780,780,781,782,783          $PANEL 4            $CND0650
      786,787,788,789,789,790,791,792          $PANEL 4            $CND0660
      801,802,803,804,804,805,806,807          $PANEL 5            $CND0670
      810,811,812,813,813,814,815,816          $PANEL 5            $CND0680
      825,826,827,828,828,829,830,831          $PANEL 6            $CND0690
      834,835,836,837,837,838,839,840          $PANEL 6            $CND0700
      849,850,851,852,852,853,854,855          $PANEL 7            $CND0710
      858,859,860,861,861,862,863,864          $PANEL 7            $CND0720
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     873,874,875,876,876,877,878,879            $PANEL 8          $CND0730
    882,883,884,885,885,886,887,888,3.927239   $PANEL 8          $CND0740
REM SOLID CONNECTOR - NUMBER 707                                  $CND0750
     707,706,707,709,710,715,716,718,719        $PANEL 1          $CND0760
     730,731,733,734,739,740,742,743            $PANEL 2          $CND0770
     754,755,757,758,763,764,766,767            $PANEL 3          $CND0780
     778,779,781,782,787,788,790,791            $PANEL 4          $CND0790
     802,803,805,806,811,812,814,815            $PANEL 5          $CND0800
     826,827,829,830,835,836,838,839            $PANEL 6          $CND0810
     850,851,853,854,859,860,862,863            $PANEL 7          $CND0820
    874,875,877,878,883,884,886,887,3.422037   $PANEL 8          $CND0830
REM SOLID CONDUCTOR - NUMBER 708                                  $CND0840
     708,704,713,712,721,728,737,736,745        $PANELS 1-2       $CND0850
     752,761,760,769,776,785,784,793            $PANELS 3-4       $CND0860
     800,809,808,817,824,833,832,841            $PANELS 5-6       $CND0870
    848,857,856,865,872,881,880,889,.106059    $PANEL 8          $CND0880
REM SOLID CONDUCTOR - NUMBER 709                                  $CND0890
     709,705,714,708,717,711,720                $PANEL 1          $CND0900
     729,738,732,741,735,744                    $PANEL 2          $CND0910
     753,762,756,765,759,768                    $PANEL 3          $CND0920
     777,786,780,789,783,792                    $PANEL 4          $CND0930
     801,810,804,813,807,816                    $PANEL 5          $CND0940
     825,834,828,837,831,840                    $PANEL 6          $CND0950
     849,858,852,861,855,864                    $PANEL 7          $CND0960
    873,882,876,885,879,888,.1829098  $PANEL 8                    $CND0970
REM SOLID CONDUCTOR - NUMBER 710                                  $CND0980
     710,706,715,707,716,709,718,710,719        $PANEL 1          $CND0990
     730,739,731,740,733,742,734,743            $PANEL 2          $CND1000
     754,763,755,764,757,766,758,767            $PANEL 3          $CND1010
     778,787,779,788,781,790,782,791            $PANEL 4          $CND1020
     802,811,803,812,805,814,806,815            $PANEL 5          $CND1030
     826,835,827,836,829,838,830,839            $PANEL 6          $CND1040
     850,859,851,860,853,862,854,863            $PANEL 7          $CND1050
    874,883,875,884,877,886,878,887,.0727762   $PANEL 8          $CND1060
REM SOLID CONDUCTOR  -  NUMBER 711
    711,701,893,702,893,703,893,712,893,721,893,724,893,723,893
    722,893,713,893,704,893                          $PANEL 1
    725,893,726,893,727,893,736,893,745,893,748,893,747,893
    746,893,737,893,728,893                          $ PANEL 2
    749,893,750,893,751,893,760,893,769,893,772,893,771,893
    770,893,761,893,752,893                          $ PANEL 3
    773,893,774,893,775,893,784,893,793,893,796,893,795,893
    794,893,785,893,776,893                          $ PANEL 4
    797,893,798,893,799,893,808,893,817,893,820,893,819,893
    818,893,809,893,800,893                          $ PANEL 5
    821,893,822,893,823,893,832,893,841,893,844,893,843,893
    842,893,833,893,824,893                          $ PANEL 6
    845,893,846,893,847,893,856,893,865,893,868,893,867,893
    866,893,857,893,848,893                          $ PANEL 7
    869,893,870,893,871,893,880,893,889,893,892,893,891,893
    890,893,881,893,872,893,.0109890                 $ PANEL 8
REM                                                               $CND1070
REM CONVECTION CONDUCTORS                                         $CND1080
REM                                                               $CND1090
    1001,602,708,,1002,603,717,,1003,604,735,,1004,605,744,       $CND1100
    1005,606,753,,1006,607,762,,1007,608,780,,1008,609,789,       $CND1110
    1009,610,807,,1010,611,816,,1011,612,825,,1012,613,834,       $CND1120
    1013,614,852,,1014,615,861,,1015,616,879,,1016,617,888,       $CND1130
    1017,620,711,,1018,621,720,,1019,622,729,,1020,623,738,       $CND1140
    1021,624,756,,1022,625,765,,1023,626,783,,1024,627,792,       $CND1150
    1025,628,801,,1026,629,810,,1027,630,828,,1028,631,837,       $CND1160
    1029,632,855,,1030,633,864,,1031,634,873,,1032,635,882,       $CND1170
    1033,638,705,,1034,639,714,,1035,640,732,,1036,641,741,       $CND1180
    1037,642,759,,1038,643,768,,1039,644,777,,1040,645,786,       $CND1190
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     1041,646,804,,1042,647,813,,1043,648,831,,1044,649,840,        $CND1200
     1045,650,849,,1046,651,858,,1047,652,876,,1048,653,885,        $CND1210
REM                                                                 $CND1220
REM  PRESSURE CONDUCTORS   (SYSTEM 1)                               $CND1230
REM                                                                 $CND1240
     501,501,502,
     502,502,503,
     503,503,504,
     504,504,505,
     505,505,506,
     506,506,507,
     507,507,508,
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     524,524,525,
     525,525,526,
     526,526,527,
     527,516,526,                                                   $CND1260
REM                                                                 $CND1270
REM  PRESSURE CONDUCTORS   (SYSTEM 2)                               $CND1280
REM                                                                 $CND1290
     528,528,529,
     529,529,530,
     530,530,531,
     531,531,532,
     532,532,533,
     533,533,534,
     534,534,535,
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     540,540,541,
     541,541,542,
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     551,551,552,
     552,552,553,
     553,553,554,
     554,543,553,                                                   $CND1310
REM                                                                 $CND1320
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REM PRESSURE CONDUCTORS  (SYSTEM 3)                          $CND1330
REM                                                          $CND1340
    555,555,556,
    556,556,557,
    557,557,558,
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    559,559,560,
    560,560,561,
    561,561,562,
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    571,571,572,
    572,572,573,
    573,573,574,
    574,574,575,
    575,575,576,
    576,576,577,
    577,577,578,
    578,578,579,
    579,579,580,
    580,580,581,
    581,570,580,                                             $CND1360
REM                                                          $CND1370
REM FLUID FLOW CONDUCTORS (SYSTEM 1)                         $CND1390
REM                                                          $CND1400
    601,-601,602,
    602,-602,603,
    603,-603,604,
    604,-604,605,
    605,-605,606,
    606,-606,607,
    607,-607,608,
    608,-608,609,
    609,-609,610,
    610,-610,611,
    611,-611,612,
    612,-612,613,
    613,-613,614,
    614,-614,615,
    615,-615,616,
    616,-616,617,
    617,-617,618,
    618,-611,618,                                            $CND1420
REM                                                          $CND1430
REM FLUID FLOW CONDUCTORS (SYSTEM 2)                         $CND1440
REM                                                          $CND1450
    619,-619,620,
    620,-620,621,
    621,-621,622,
    622,-622,623,
    623,-623,624,
    624,-624,625,
    625,-625,626,
    626,-626,627,
    627,-627,628,
    628,-628,629,
    629,-629,630,
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     630,-630,631,
     631,-631,632,
     632,-632,633,
     633,-633,634,
     634,-634,635,
     635,-635,636,
     636,-629,636,                                                          $CND1470
REM                                                                         $CND1480
REM FLUID FLOW CONDUCTORS (SYSTEM 3)                                        $CND1490
REM                                                                         $CND1500
     637,-637,638,
     638,-638,639,
     639,-639,640,
     640,-640,641,
     641,-641,642,
     642,-642,643,
     643,-643,644,
     644,-644,645,
     645,-645,646,
     646,-646,647,
     647,-647,648,
     648,-648,649,
     649,-649,650,
     650,-650,651,
     651,-651,652,
     652,-652,653,
     653,-653,654,
     654,-647,654,                                                          $CND1520
REM                                                                         $CND1530
REM RADIATION CONDUCTOR - NUMBER 901                                        $CND1540
      -901,701,901,703,901,722,901,724,901                         $PANEL 1$CND1550
      725,902,727,902,746,902,748,902                              $PANEL 2$CND1560
      749,903,751,903,770,903,772,903                              $PANEL 3$CND1570
      773,904,775,904,794,904,796,904                              $PANEL 4$CND1580
      797,905,799,905,818,905,820,905                              $PANEL 5$CND1590
      821,906,823,906,842,906,844,906                              $PANEL 6$CND1600
      845,907,847,907,866,907,868,907                              $PANEL 7$CND1610
      869,908,871,908,890,908,892,908,.229827E-9                   $PANEL 8$CND1620
REM                                                                         $CND1630
REM RADIATION CONDUCTOR - NUMBER 902                                        $CND1640
REM                                                                         $CND1650
      -902,702,901,723,901,726,902,747,902                       $PANEL 1-2$CND1660
      750,903,771,903,774,904,795,904                            $PANEL 3-4$CND1670
      798,905,819,905,822,906,843,906                            $PANEL 5-6$CND1680
     846,907,867,907,870,908,891,908,.196995E-9                  $PANEL 7-8$CND1690
REM                                                                         $CND1700
REM RADIATION CONDUCTOR - NUMBER 903                                        $CND1710
REM                                                                         $CND1720
      -903,704,901,712,901,713,901,721,901                         $PANEL 1$CND1730
      728,902,736,902,737,902,745,902                              $PANEL 2$CND1740
      752,903,760,903,761,903,769,903                              $PANEL 3$CND1750
      776,904,784,904,785,904,793,904                              $PANEL 4$CND1760
      800,905,808,905,809,905,817,905                              $PANEL 5$CND1770
      824,906,832,906,833,906,841,906                              $PANEL 6$CND1780
      848,907,856,907,857,907,865,907                              $PANEL 7$CND1790
      872,908,880,908,881,908,889,908,.523268E-9                   $PANEL 8$CND1800
REM                                                                         $CND1810
REM RADIATION CONDUCTOR - NUMBER 904                                        $CND1820
REM                                                                         $CND1830
      -904,705,[illegible]1,70[illegible],[illegible]1,711,901,7[illegible],[illegible]1,71[illegible],[illegible],7[illegible], [illegible]1$PANEL 1$[illegible]
      729,902,732,902,735,902,738,90[illegible],741,902,744,902    $PANEL 2$CND1850
      753,903,756,903,759,903,762,903,765,903,768,903              $PANEL 3$CND1860
      777,904,780,904,783,904,786,904,789,904,792,904              $PANEL 4$CND1870
      801,905,804,905,807,905,810,905,813,905,816,905              $PANEL 5$CND1880
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    825,906,828,906,831,906,834,906,837,906,840,906        $PANEL 6$CND1890
    849,907,852,907,855,907,858,907,861,907,864,907        $PANEL 7$CND1900
    873,908,876,908,879,908,882,908,885,908                        $CND1910
    888,908,.270036E-9                                             $CND1920
REM                                                                $CND1930
REM RADIATION CONDUCTOR - NUMBER 905                               $CND1940
REM                                                                $CND1950
    -905,706,901,707,901,709,901,710,901                   $PANEL 1$CND1960
    715,901,716,901,718,901,719,901                        $PANEL 1$CND1970
    730,902,731,902,733,902,734,902                        $PANEL 2$CND1980
    739,902,740,902,742,902,743,902                        $PANEL 2$CND1990
    754,903,755,903,757,903,758,903                        $PANEL 3$CND2000
    763,903,764,903,766,903,767,903                        $PANEL 3$CND2010
    778,904,779,904,781,904,782,904                        $PANEL 4$CND2020
    787,904,788,904,790,904,791,904                        $PANEL 4$CND2030
    802,905,803,905,805,905,806,905                        $PANEL 5$CND2040
    811,905,812,905,814,905,815,905                        $PANEL 5$CND2050
    826,906,827,906,829,906,830,906                        $PANEL 6$CND2060
    835,906,836,906,838,906,839,906                        $PANEL 6$CND2070
    850,907,851,907,853,907,854,907                        $PANEL 7$CND2080
    859,907,860,907,862,907,863,907                        $PANEL 7$CND2090
    874,908,875,908,877,908,878,908                        $PANEL 8$CND2100
    883,908,884,908,886,908,887,908,.359122E-9             $PANEL 8$CND2110
REM                                                                $CND2120
END                                                                $CND2130
BCD 3CONSTANTS DATA                                                $CNS0010
   TIMEND, 6.2, OUTPUT, 0.05
   1,3.6,2,28,3,15,4,10,5,27 $K5 IS NO PRESSURE COND PEP SYSTEM $CNS0030
   6,85.,7,0.0001,8,0.0001                  $  WATER GLYCOL FLOW RATE
   9,0,10,0,11,0                            $  BYPASS OPTION
REM CONSTANTS FOR INCIDENT HEAT -- PANELS 1-8                      $CNS0060
   12,,13,,14,,15,39.,16,83.,17,82.,18,40.,19,                     $CNS0070
   20,24  $ NUMBER OF NODES PER PANEL                              $CNS0080
   21,.374223E-3 $ VOLUME OF FLUID CAPACITANCE NODES               $CNS0090
   22,16  $ NO. OF NODES PER SYSTEM WITH CAPACITANCE VALUES        $CNS0100
   23,3.60                                                         $CNS0110
REM -K22 IS  NO. OF CONVECTION CONDUCTORS PER SYSTEM               $CNS0120
   24,18  $ NO. OF THERMAL FLUID FLOW CONDUCTORS PER SYSTEM        $CNS0130
   25,.6944444E-2 $ CONVERSION FROM PSF TO PSI                     $CNS0140
REM CONSTANTS USED IN OUTPUT CALLS                                 $CNS0150
   26,,27,16,28,,29, STEMP,30,192,31,701,32,,33,NO USE$
REM MULTIPLYING FACTORS FOR PRESSURE CONDUCTORS                    $CNS0170
   501,255.91,502,108.265,503,108.265,504,30.57,505,108.265        $CNS0180
   506,108.265,507,53.03,508,108.265,509,108.265,510,65.726        $CNS0190
   511,108.265,512,108.265,513,49.71,514,108.265,515,108.265       $CNS0200
   516,33.01,517,108.265,518,108.265,519,59.7692,520,108.265       $CNS0210
   521,108.265,522,58.0113,523,108.265,524,108.265,525,36.0373     $CNS0220
   526,55.2666,527,148.1534,528,285.9462,529,108.265               $CNS0230
   530,108.265,531,30.7636,532,108.265,533,108.265,534,67.6798     $CNS0240
   535,108.265,536,108.265,537,49.71,538,108.265,539,108.265       $CNS0250
   540,49.4174,541,108.265,542,108.265,543,66.5079,544,108.265     $CNS0260
   545,108.265,546,43.9479,547,108.265,548,108.265,549,59.3824     $CNS0270
   550,108.265,551,108.265,552,47.0735,553,68.8417,554,159.4818    $CNS0280
   555,295.3176,556,108.265,557,108.265,558,46.7802,559,108.265    $CNS0290
   560,108.265,561,52.0539,562,108.265,563,108.265,564,50.296      $CNS0300
   565,108.265,566,108.265,567,65.2422,568,108.265,569,108.265     $CNS0310
   570,43.5577,571,108.265,572,108.265,573,44.4363,574,108.265     $CNS0320
   575,108.265,576,73.8325,577,108.265,578,108.265,579,40.9204     $CNS0330
   580,68.8717,581,158.5055                                        $CNS0340
REM COMPRESSED PRESSURE CONDUCTORS                                 $CNS0350
   582,,583,,584,,585,,586,,587,,588,,589,,590,,591,,592,,593,     $CNS0360
   594,0.,595,7                                                    $CNS0370
   598,150.0    $INITIAL SOLID NODE TEMP
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    599,192    $ NO. OF SOLID TEMPERATURE NODES                          $CNS0390
    600, 6.2
REM CONSTANTS 601 TO 681 * 4/WP AND ARE USED IN RE NO. COMPUTATN $CNS0410
    601,66.427,602,37.619,603,37.619,604,50.087,605,37.619          $CNS0420
    606,37.619,607,50.087,608,37.619,609,37.619,610,50.087          $CNS0430
    611,37.619,612,37.619,613,50.087,614,37.619,615,37.619          $CNS0440
    616,50.087,617,37.619,618,37.619,619,50.087,620,37.619          $CNS0450
    621,37.619,622,50.087,623,37.619,624,37.619,625,50.087          $CNS0460
    626,50.087,627,50.087,628,66.427,629,37.619,630,37.619          $CNS0470
    631,50.087,632,37.619,633,37.619,634,50.087,635,37.619          $CNS0480
    636,37.619,637,50.087,638,37.619,639,37.619,640,50.087          $CNS0490
    641,37.619,642,37.619,643,50.087,644,37.619,645,37.619          $CNS0500
    646,50.087,647,37.619,648,37.619,649,50.087,650,37.619          $CNS0510
    651,37.619,652,50.087,653,50.087,654,50.087,655,66.427          $CNS0520
    656,37.619,657,37.619,658,50.087,659,37.619,660,37.619          $CNS0530
    661,50.087,662,37.619,663,37.619,664,50.087,665,37.619          $CNS0540
    666,37.619,667,[illegible].087,[illegible]68,37.61[illegible]69,[illegible],670,[illegible]          $C[illegible]
    671,37.619,672,37.619,673,50.087,674,37.619,675,37.619          $CNS0560
    676,50.087,677,37.619,678,37.619,679,50.087,680,50.087          $CNS0570
    681,50.087,682,,683,,684,                                        $CNS0580
    701,.080311,702,0.,703,0.,704,.042633,705,0.,706,0.              $CNS0590
    707,.042633,708,0.,709,0.,710,.042633,711,0.,712,0.              $CNS0600
    713,.042633,714,0.,715,0.,716,.042633,717,0.,718,0.              $CNS0610
    719,.042633,720,0.,721,0.,722,.042633,723,0.,724,0.              $CNS0620
    725,.023644,726,.0023271,727,.0472876,728,.080311                $CNS0630
    729,0.,730,0.,731,.042633,732,0.,733,0.,734,.042633,735,0.       $CNS0640
    736,0.,737,.042633,738,0.,739,0.,740,.042633,741,0.,742,0.       $CNS0650
    743,.042633,744,0.,745,0.,746,.042633,747,0.,748,0.              $CNS0660
    749,.042633,750,0.,751,0.,752,.023644,753,.0023271               $CNS0670
    754,.0472876,755,.080311,756,0.,757,0.,758,.042633,759,0.        $CNS0680
    760,0.,761,.042633,762,0.,763,0.,764,.042633,765,0.,766,0.       $CNS0690
    767,.042633,768,0.,769,0.,770,.042633,771,0.,772,0.              $CNS0700
    773,.042633,774,0.,775,0.,776,.042633,777,0.,778,0.              $CNS0710
    779,.023644,780,.0023271,781,.0472876                            $CNS0720
    801,,802,,803,    $ FLUID HEAT LOSS PER SYSTEM                   $CNS0730
    804,.0265823$(WP/4) FOR PANEL TUBES                              $CNS0740
REM CONSTANTS FOR GR NUMBER =  (WP/4)*(X/D)                          $CNS0750
    805,.984934,806,4.725,807,.984934,808,4.725                      $CNS0760
    809,.984934,810,4.725,811,.984934,812,4.725                      $CNS0770
    813,.984934,814,4.725,815,.984934,816,4.725                      $CNS0780
    817,.984934,818,4.725,819,.984934,820,4.725                      $CNS0790
    821,,822,,823,    $INVERSE FLOW RATE                             $CNS0800
    824,,825,,826,  $ SYSTEM PRESSURE DROP                           $CNS0810
    827,150.,828,150.,829,150.            $  PREVIOUS TSRCE
    830, 22., 831, 22., 832, 22.          $  MASS OF KOH
    833,.73,834,.73,835,.73               $  PERCENT KOH IN STACK
    836, 160., 837, 160., 838, 160.       $  TCE
    839, 85.8                             $  GAS CONSTANT - WATER
    840, 767.                             $  GAS CONSTANT H2
    841,180.,842,180.,843,180.            $  VOLUMETRIC FLOW RATE
    844,340.,845,340.,846,340.            $  STACK INLET TEMP
    847,420.,848,420.,849,420.            $  STACK OUTLET TEMPS
    850,-.60, 851,-.60, 852,-.60          $ PC H2O PROD. IN STACK
    853, 0.023                            $  H2O PRODUCTION RATE
    854,30.,855,0.,856,0.                 $  CURRENT  -  AMPS
    857, 0.01                             $ ACCEPTABLE ERROR FOR RATE
    858,,859,,860,                        $  CELL VOLTAGE
    861, 0.                               $  NOT USED
    862, 30.                              $  MCP OF STACK
    863, 0.                               $  NOT USED
    864,2.43E-3      $VOL,FT**3,RAD OUT TO REG COLD INLET
    865,1.545E-2      $VOL,FT**3,REG COLD SIDE
    866,3.76E-3      $VOL,FT**3,COND GLYCOL SIDE
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     867,4.63E-3     $VOL,FT**3,COND OUTLET TO REG. INLET
     868,2.431E-2     $    ,FT**3,SECONDARY REG HOT SIDE
     869,2.26E-3     $VOL.FT**3,REG. TO RAD INLET
     870,160.,871,160.,872,160.     $TCE, PREVIOUS TIME STEP
     873,1,874,1,875,1          $INTEGER POINTER FOR SEC BP VLV
     876,,877,,878,                             $  TEMP COND INLET
     879,.5,880,.5,881,.5     $SECONDARY BYPASSED FRACTION
     882,130.,883,130.,884,130.     $SEC REG COLD OUTLET
     885,.95     $BYPASS FRACTION CUTOFF VALUE
     886,,887,,888,     $INVERSE FLOW RATES
     889,0.25     $REG DELAY ADJ FACTOR
     890,100.,891,100.,892,100.     $REG COLD SIDE INLET
     893,175.,894,175.,895,175.     $COND GLY OUT TEMP
     896,175.,897,175.,898,175.     $SEC REG HOT SIDE INLET
     899,100.,900,100.,901,100.     $SEC REG HOT SIDE OUTLET
     902,1.,903,1.,904,1.                       $  INTEGERS USED FOR DO LOOPS
     905,,906,,907,                             $  INTEGERS USED FOR BY PASS
     908,150.07,909,150.07,910,150.07           $  COND GLY INLET TEMP
     911, 1.     $COND HEAT BAL TOLERANCE
     912,200  $ARRAY IC
     913,199  $ARRAY IC
     914,20   $ARRAY IC
     915,40   $ARRAY IC
     916,30   $ARRAY IC
     917,,918,,919,                             $  POWER  -  WATTS
     920,77.29,921,77.29,922,77.29              $  H2O SPECIFIC VOLUME
     923,,924,,925,                             $  PERCENT BY-PASS PRIMARY
     926,,927,,928,                             $  STACK EXIT PRESSURE
     929,,930,,931,                             $  PERCENT KOH
     932,,933,,934,                             $  H2O PRESSURE
     935,,936,,937,                             $  ENTHALPY OF STEAM
     938,,939,,940,                             $  INITIAL PRESSURE
     941,,942,,943,                             $  INITIAL SPECIFIC VOLUME
     944,70.,945,70.,946,70.                    $  AMBIENT TEMP DEG F
     947,0.00257                                $  H2 PRODUCTION RATE
     948,5772.79                                $LOWER HEATING VALUE, H2
     949,6824.42                                $HIGHER HEATING VALUE, H2
     950,0.2                                    $ERROR FOR STACK INLET
     951, 5.     $INITIAL COND TEMP INCREMENT
     952, +1     $INTEGER INDICATOR FOR COND IMBAL
     953,1.0                                    $ERROR FOR HEAT BALANCE
     954,0.2                                    $ERROR FOR STACK INLET TEMP
     955,,956,,957,                             $WATER CONDENSED-LB/HR
     958,,959,,960,                             $STACK WATER STORAGE RATE
     961,0.5,962,0.5,963,0.5                    $  SEC BP VLV STAT POS
     964,530.                                   $  O2 INLET TEMP  -  DEGR
     965,530.                                   $  H2 INLET TEMP  -  DEGR
     966,0.48                                   $  O2 FLOW RATE  -  LB/HR
     967,0.06                                   $  H2 FLOW RATE  -  LB/HR
     968,100.,969,100.,970,100.                 $  O2 REACTANT TEMP TO STACK
     971,100.,972,100.,973,100.                 $  H2 REACTANT TEMP TO STACK
     974,,975,,976,                             $  FLOW RATE FIX-UP
END                                                                   $CNS1050
BCD 3ARRAY DATA                                                       $ARR0010
     1   $ DENSITY OF GLYCOL-WATER          LBM/FT**3                 $ARR0020
     -460.,75.09,-50.,69.54,-40.,69.4,-30.,69.25,-20.,69.1            $ARR0030
     -10.,68.93,0.,68.76,10.,68.58,20.,68.4,30.,68.2,40.,68.1         $ARR0040
     50.,67.83,60.,67.63,70.,67.43,80.,67.22,90.,67.,100.,66.78       $ARR0050
     110.,66.56,120.,66.34,130.,66.1,140.,65.85,150.,65.61            $ARR0060
     160.,65.35,170.,65.1,180.,64.84,190.,64.57,200.,64.23            $ARR0070
     250.,62.79,300.,61.23,350.,59.61,END                             $ARR0080
     2   $ CONDUCTIVITY OF GLYCOL-WATER     BTU/HR*FT*F               $ARR0090
     -460.,.2279,-50.,.2279,-40.,.2279,-30.,.2278,-20.,.2277          $ARR0100
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    -10.,.2275,0.,.2273,10.,.2270,20.,.2266,30.,.2262,40.,.2258  $ARR0110
    50.,.2252,60.,.2246,70.,.2240,80.,.2233,90.,.2225,100.,.2217 $ARR0120
    110.,.2208,120.,.2199,130.,.2189,140.,.2178,150.,.2167       $ARR0130
    160.,.2156,170.,.2143,180.,.2130,190.,.2117,200.,.2103       $ARR0140
    340.,.1844,END                                               $ARR0150
    3   $ SPECIFIC HEAT OF GLYCOL-WATER    BTU/LBM*F             $ARR0160
    -460.,.033,-50.,.606,-40.,.618,-30.,.631,-20.,.643           $ARR0170
    -10.,.655,0.,.666,10.,.677,20.,.688,30.,.698,40.,.708        $ARR0180
    50.,.718,60.,.728,70.,.737,80.,.746,90.,.754,100.,.762       $ARR0190
    110.,.770,120.,.777,130.,.784,140.,.791,150.,.797,160.,.803  $ARR0200
    170.,.809,180.,.814,190.,.819,200.,.824,230.,.84             $ARR0210
    270.,.86,310.,.878,END                                       $ARR0211
    4   $ VISCOSITY OF GLYCOL-WATER        E-3 LBM/FT*SEC        $ARR0220
    -450.,500000.,-50.,245.,-40.,135.,-30.,80.,-20.,51.9,-10.    $ARR0230
    34.,0.,24.5,10.,16.5,20.,12.2,30.,9.3,40.,7.3,50.,5.75       $ARR0240
    60.,4.65,70.,3.75,80.,3.05,90.,2.58,100.,2.08,110.,1.87      $ARR0250
    120.,1.61,130.,1.4,140.,1.22,150.,1.11,160.,.96,170.,.86     $ARR0260
    180.,.77,190.,.69,200.,.625,250.,.406,300.,.303              $ARR0270
    350.,.216,END                                                $ARR0271
    5,SPACE,28,END                                               $ARR0280
    6,SPACF,28,END                                               $ARR0290
    7,SPACE,28,END                                               $ARR0300
    8,SPACE,81,END                                               $ARR0310
    9,SPACE,54,END                                               $ARR0320
    10 $BYPASSED FRACTION -- SECONDARY BP VLV-ASCENDING TCE
    157.,0.0,157.25,0.165,157.5,0.245,157.75,0.3,158.,0.34
    158.25,0.38,158.5,0.41,158.75,0.43,159.,0.445,159.25,0.46
    159.5,0.47,159.75,0.474,160.,0.48,160.25,0.485,160.5,0.49
    160.75,0.493,161.,0.498,161.25,0.5,161.5,0.51,161.75,0.52
    162.,0.534,162.25,0.555,162.5,0.58,162.75,0.615,163.,0.65
    163.25,0.71,163.5,0.8,163.75,0.935,164.,1.0,END
    11 $BYPASSED FRACTION -- SECONDARY BP VLV-DESCENDING TCE
    154.,0.0,154.25,0.12,154.5,0.195,154.75,0.255,155.,0.31
    155.25,0.365,155.5,0.4,155.75,0.425,156.,0.44,156.25,0.457
    156.5,0.467,156.75,0.475,157.0,0.48,157.25,0.485,157.5,0.488
    157.75,0.492,158.,0.5,158.25,0.506,158.5,0.512,158.75,0.522
    159.,0.535,159.25,0.554,159.5,0.58,159.75,0.62,160.,0.665
    160.25,0.74,160.5,0.88,160.75,0.94,161.,1.0,END
    12,.145833,.125000,.145833,.332031,.171347,.227875,.227875   $ARR0350
       .171347,.227875,.227875,.171347,.332031,.332031,.171347   $ARR0360
       .227875,.227875,.171347,.227875,.227875,.171347,.332031   $ARR0370
       .145833,.125000,.145833,END                               $ARR0380
REM THE FOLLOWING ARRAYS PROVIDE FOR VARIABLE INCIDENT HEAT FLUX $ARR0390
    13  $ INCIDENT HEAT FOR PANEL 1 - BTU/HR FT**2               $ARR0400
    0.00,07.09,0.05,15.67,0.10,23.90,0.15,31.45,0.20,38.00       $PANEL1
    0.25,43.30,0.30,47.13,0.35,49.33,0.40,49.81,0.45,48.55       $PANEL1
    0.50,45.60,0.55,41.09,0.60,35.20,0.65,28.16,0.70,20.27       $PANEL1
    0.75,11.84,0.80,07.09,1.55,07.09,END                         $PANEL1
    14  $ INCIDENT HEAT FOR PANEL 2 - BTU/HR FT**2               $ARR0420
    0.00,00.27,0.05,15.58,0.10,30.26,0.15,43.73,0.20,55.43       $PANEL2
    0.25,64.88,0.30,71.71,0.35,75.63,0.40,76.48,0.45,74.24       $PANEL2
    0.50,68.98,0.55,60.94,0.60,50.42,0.65,37.86,0.70,23.77       $PANEL2
    0.75,08.74,0.80,00.27,1.55,00.27,END                         $PANEL2
    15  $ INCIDENT HEAT FOR PANEL 3 - BTU/HR FT**2               $ARR0440
    0.00,00.00,0.05,16.82,0.10,32.96,0.15,47.75,0.20,60.61       $PANEL3
    0.25,71.00,0.30,78.50,0.35,82.81,0.40,83.75,0.45,81.28       $PANEL3
    0.50,75.51,0.55,66.66,0.60,55.11,0.65,41.31,0.70,25.83       $PANEL3
    0.75,09.31,0.80,00.00,1.55,00.00,END                         $PANEL3
    16  $ INCIDENT HEAT FOR PANEL 4 - BTU/HR FT**2               $ARR0460
    0.00,08.91,0.05,16.24,0.10,23.28,0.15,29.74,0.20,35.34       $PANEL4
    0.25,39.88,0.30,43.15,0.35,45.03,0.40,45.44,0.45,44.36       $PANEL4
    0.50,41.84,0.55,37.99,0.60,32.94,0.65,26.93,0.70,20.18       $PANEL4
    0.75,12.97,0.80,08.91,1.55,08.91,END                         $PANEL4
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17  $ INCIDENT HEAT FOR PANEL 5 - BTU/HR FT**2                    $ARR0480
0.00,32.37,0.05,35.41,0.10,38.32,0.15,41.00,0.20,43.32           $PANEL5
0.25,45.20,0.30,46.56,0.35,47.34,0.40,47.51,0.45,47.06           $PANEL5
0.50,46.02,0.55,44.41,0.60,42.33,0.65,39.83,0.70,37.04           $PANEL5
0.75,34.05,0.80,35.82,0.85,43.35,0.90,32.37,1.45,32.37           $PANEL5
1.50,40.76,1.55,32.37,END                                         $PANEL5
18  $ INCIDENT HEAT FOR PANEL 6 - BTU/HR FT**2                    $ARR0500
0.00,49.71,0.05,54.38,0.10,58.86,0.15,62.97,0.20,66.54           $PANEL6
0.25,69.42,0.30,71.50,0.35,72.70,0.40,72.96,0.45,72.28           $PANEL6
0.50,70.67,0.55,68.22,0.60,65.01,0.65,61.18,0.70,56.88           $PANEL6
0.75,52.29,0.80,56.54,0.85,71.47,0.90,49.71,1.45,49.71           $PANEL6
1.50,66.34,1.55,49.71,END                                         $PANEL6
19  $ INCIDENT HEAT FOR PANEL 7 - BTU/HR FT**2                    $ARR0520
0.00,56.74,0.05,62.08,0.10,67.19,0.15,71.88,0.20,75.95           $PANEL7
0.25,79.25,0.30,81.62,0.35,82.99,0.40,83.29,0.45,82.50           $PANEL7
0.50,80.67,0.55,77.87,0.60,74.21,0.65,69.84,0.70,64.93           $PANEL7
0.75,59.69,0.80,64.60,0.85,81.75,0.90,56.74,1.45,56.74           $PANEL7
1.50,75.86,1.55,56.74,END                                         $PANEL7
20  $ INCIDENT HEAT FOR PANEL 8 - BTU/HR FT**2                    $ARR0540
0.00,31.81,0.05,34.80,0.10,37.66,0.15,40.29,0.20,42.57           $PANEL8
0.25,44.42,0.30,45.75,0.35,46.52,0.40,46.68,0.45,46.25           $PANEL8
0.50,45.22,0.55,43.65,0.60,41.60,0.65,39.15,0.70,36.40           $PANEL8
0.75,33.46,0.80,35.13,0.85,42.39,0.90,31.81,1.45,31.81           $PANEL8
1.50,39.90,1.55,31.81,END                                         $PANEL8
21,SPACE,56,END                                                   $ARR0560
22,SPACE,81,END $ REYNOLDS NUMBER                                 $ARR0570
23,SPACE,81,END                                                   $ARR0580
24 $RELATIVE ENTHALPY OF GLYCOL-WATER,BTU/LBM
-460.,0.0,-50.,131.0,-40.,137.12,-30.,143.36,-20.,149.73
-10.,156.22,0.0,162.83,10.,169.54,20.,176.37,30.,183.3
40.,190.33,50.,197.46,60.,204.69,70.,212.01,80.,219.43
90.,226.93,100.,234.51,110.,242.17,120.,249.9,130.,257.71
140.,265.58,150.,273.52,160.,281.52,170.,289.58,180.,297.7
190.,305.86,200.,314.08,230.,339.04,270.,373.04,310.,407.8
END
25,SPACE,48,END                                                   $ARR0600
26  $  DO LOOP INDICES  -  INITIAL VALUE
0.,1.,6.2,1.,END
27  $  DO LOOP INDICES  -  TEST VALUE
0.,1.,6.2,1.,END
28  $  DO LOOP INDICES  -  INCREMENT
0.,1.,6.2,1.,END
29,SPACE,10,END                          $  NOT USED
30,SPACE,10,END                          $  NOT USED
31,SPACE,10,END                          $  NOT USED
32,SPACE,10,END                          $  NOT USED
33,SPACE,10,END                          $  NOT USED
34,SPACE,10,END                          $  NOT USED
35  $  BYPASS OPTION  -  SYSTEM 1
0.,0.,3.1,0.,3.101,1.,6.2,1.,END
36  $  BYPASS OPTION  -  SYSTEM 2
0.,0.,6.2,0.,END
37  $  BYPASS OPTION  -  SYSTEM 3
0.,0.,6.2,0.,END
38      $      HEAT TRANSFER COEFFICIENT - AREA TERM
11,11,50.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.   $TVA0001
120.,209.,243.,265.,289.,318.,345.,377.,0.,0.,0.,0.          $TVA0002
130.,205.,238.,258.,281.,308.,333.,362.,404.,0.,0.,0.        $TVA0003
140.,202.,234.,253.,275.,300.,323.,350.,387.,0.,0.,0.        $TVA0004
150.,199.,230.,248.,269.,293.,315.,339.,374.,408.,0.,0.      $TVA0005
160.,197.,227.,244.,264.,287.,307.,330.,363.,395.,0.,0.      $TVA0006
170.,195.,224.,241.,260.,282.,301.,323.,353.,383.,417.,0.    $TVA0007
180.,193.,221.,237.,256.,276.,295.,315.,344.,371.,404.,0.    $TVA0008
190.,190.,218.,234.,251.,272.,289.,308.,335.,361.,391.,417.  $TVA0009
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200.,189.,216.,231.,249.,268.,285.,303.,329.,354.,381.,406.   $TVA0010
210.,189.,216.,231.,248.,268.,284.,303.,329.,354.,381.,406.   $TVA0011
220.,187.,214.,229.,245.,264.,280.,298.,323.,346.,372.,395.   $TVA0012
11,11,55.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.    $TVA0013
120.,223.,263.,287.,312.,342.,373.,409.,0.,0.,0.,0.           $TVA0014
130.,220.,258.,280.,304.,332.,360.,393.,434.,0.,0.,0.         $TVA0015
140.,216.,254.,275.,297.,323.,349.,380.,417.,0.,0.,0.         $TVA0016
150.,213.,250.,270.,291.,316.,340.,369.,403.,438.,0.,0.       $TVA0017
160.,211.,246.,265.,285.,309.,332.,359.,391.,423.,0.,0.       $TVA0018
170.,208.,243.,262.,281.,304.,325.,351.,381.,411.,449.,0.     $TVA0019
180.,206.,240.,258.,276.,298.,319.,343.,371.,399.,435.,0.     $TVA0020
190.,203.,237.,254.,272.,293.,313.,335.,362.,388.,421.,452.   $TVA0021
200.,202.,234.,251.,269.,289.,308.,330.,356.,381.,412.,441.   $TVA0022
210.,202.,234.,251.,269.,289.,308.,330.,355.,380.,411.,440.   $TVA0023
220.,200.,232.,248.,265.,285.,303.,324.,348.,372.,402.,429.   $TVA0024
11,11,60.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.    $TVA0025
120.,240.,285.,310.,334.,365.,398.,438.,0.,0.,0.,0.           $TVA0026
130.,236.,279.,303.,325.,354.,384.,421.,462.,0.,0.,0.         $TVA0027
140.,233.,274.,296.,318.,345.,373.,407.,444.,0.,0.,0.         $TVA0028
150.,230.,270.,291.,311.,337.,363.,395.,429.,467.,0.,0.       $TVA0029
160.,227.,266.,286.,306.,330.,355.,385.,417.,452.,0.,0.       $TVA0030
170.,225.,263.,282.,301.,324.,348.,376.,407.,439.,478.,0.     $TVA0031
180.,222.,259.,278.,296.,319.,341.,368.,396.,426.,463.,0.     $TVA0032
190.,220.,256.,274.,292.,313.,335.,360.,387.,415.,449.,483.   $TVA0033
200.,218.,253.,271.,288.,309.,330.,354.,380.,407.,439.,472.   $TVA0034
210.,218.,253.,271.,288.,309.,330.,354.,380.,406.,439.,470.   $TVA0035
220.,216.,252.,268.,285.,305.,325.,348.,372.,398.,429.,459.   $TVA0036
11,11,65.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.    $TVA0037
120.,256.,305.,331.,354.,385.,421.,462.,0.,0.,0.,0.           $TVA0038
130.,252.,299.,324.,345.,374.,407.,445.,488.,0.,0.,0.         $TVA0039
140.,248.,294.,317.,338.,364.,395.,430.,470.,0.,0.,0.         $TVA0040
150.,245.,289.,311.,331.,356.,385.,418.,454.,494.,0.,0.       $TVA0041
160.,242.,285.,307.,325.,349.,377.,408.,442.,477.,0.,0.       $TVA0042
170.,240.,281.,302.,320.,343.,369.,399.,431.,465.,505.,0.     $TVA0043
180.,237.,278.,298.,315.,337.,362.,390.,420.,452.,489.,0.     $TVA0044
190.,234.,274.,294.,310.,331.,355.,382.,410.,440.,474.,511.   $TVA0045
200.,233.,272.,291.,307.,327.,350.,376.,403.,432.,464.,499.   $TVA0046
210.,232.,272.,291.,306.,327.,350.,376.,403.,431.,464.,498.   $TVA0047
220.,231.,269.,287.,303.,323.,345.,369.,395.,423.,454.,486.   $TVA0048
11,11,70.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.    $TVA0049
120.,266.,322.,350.,373.,403.,441.,484.,0.,0.,0.,0.           $TVA0050
130.,262.,316.,343.,364.,392.,427.,467.,512.,0.,0.,0.         $TVA0051
140.,258.,310.,336.,356.,382.,415.,452.,493.,0.,0.,0.         $TVA0052
150.,255.,306.,330.,349.,374.,405.,439.,478.,521.,0.,0.       $TVA0053
160.,252.,301.,325.,343.,367.,396.,428.,465.,505.,0.,0.       $TVA0054
170.,249.,298.,320.,337.,360.,389.,419.,453.,491.,529.,0.     $TVA0055
180.,247.,294.,316.,332.,354.,381.,410.,442.,477.,513.,0.     $TVA0056
190.,244.,290.,311.,327.,348.,374.,401.,432.,465.,498.,536.   $TVA0057
200.,242.,287.,308.,324.,344.,369.,395.,425.,456.,488.,524.   $TVA0058
210.,242.,287.,308.,323.,344.,368.,395.,424.,456.,487.,523.   $TVA0059
220.,240.,284.,305.,320.,339.,363.,389.,417.,447.,477.,510.   $TVA0060
11,11,75.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.    $TVA0061
120.,266.,334.,366.,389.,420.,460.,504.,0.,0.,0.,0.           $TVA0062
130.,262.,328.,358.,379.,408.,446.,486.,535.,0.,0.,0.         $TVA0063
140.,258.,322.,351.,371.,398.,433.,470.,515.,0.,0.,0.         $TVA0064
150.,255.,317.,345.,364.,390.,423.,458.,499.,546.,0.,0.       $TVA0065
160.,252.,313.,340.,358.,383.,414.,447.,486.,529.,0.,0.       $TVA0066
170.,250.,309.,335.,353.,376.,406.,437.,474.,515.,552.,0.     $TVA0067
180.,247.,305.,330.,347.,370.,399.,428.,463.,501.,536.,0.     $TVA0068
190.,245.,301.,326.,342.,364.,391.,419.,452.,488.,520.,559.   $TVA0069
200.,243.,299.,322.,338.,359.,386.,413.,445.,479.,510.,546.   $TVA0070
210.,243.,299.,322.,338.,359.,386.,413.,445.,479.,509.,546.   $TVA0071
220.,241.,296.,319.,334.,354.,380.,406.,437.,469.,498.,533.   $TVA0072
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11,11,80.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.   $TVA0073
120.,254.,339.,376.,401.,434.,477.,522.,0.,0.,0.,0.          $TVA0074
130.,250.,333.,368.,392.,423.,463.,504.,555.,0.,0.,0.        $TVA0075
140.,247.,327.,361.,384.,413.,450.,488.,536.,0.,0.,0.        $TVA0076
150.,244.,322.,355.,377.,404.,439.,475.,519.,568.,0.,0.      $TVA0077
160.,242.,318.,350.,370.,397.,430.,464.,506.,552.,0.,0.      $TVA0078
170.,239.,314.,345.,365.,390.,422.,455.,494.,537.,574.,0.    $TVA0079
180.,237.,310.,340.,359.,384.,415.,445.,483.,523.,557.,0.    $TVA0080
190.,235.,307.,336.,354.,378.,407.,436.,472.,510.,542.,581.  $TVA0081
200.,233.,304.,333.,350.,373.,402.,430.,464.,501.,531.,568.  $TVA0082
210.,233.,304.,332.,350.,373.,401.,430.,464.,500.,530.,567.  $TVA0083
220.,231.,301.,329.,346.,368.,396.,423.,456.,491.,519.,554.  $TVA0084
11,11,85.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.   $TVA0085
120.,230.,335.,380.,410.,447.,493.,540.,0.,0.,0.,0.          $TVA0086
130.,227.,329.,372.,401.,436.,478.,521.,574.,0.,0.,0.        $TVA0087
140.,224.,324.,365.,393.,426.,465.,506.,555.,0.,0.,0.        $TVA0088
150.,222.,319.,359.,385.,417.,454.,492.,538.,589.,0.,0.      $TVA0089
160.,220.,315.,354.,379.,410.,445.,481.,524.,572.,0.,0.      $TVA0090
170.,218.,312.,350.,374.,403.,437.,471.,512.,557.,596.,0.    $TVA0091
180.,216.,309.,345.,369.,397.,429.,462.,501.,543.,579.,0.    $TVA0092
190.,215.,305.,341.,363.,390.,422.,453.,490.,529.,563.,603.  $TVA0093
200.,213.,302.,337.,359.,386.,416.,447.,482.,520.,552.,590.  $TVA0094
210.,213.,302.,337.,359.,385.,416.,446.,482.,519.,552.,589.  $TVA0095
220.,212.,299.,334.,355.,381.,410.,439.,473.,510.,540.,580.  $TVA0096
11,11,90.,-20.,0.,20.,40.,60.,80.,100.,120.,140.,160.,180.   $TVA0097
120.,199.,322.,377.,414.,459.,507.,558.,0.,0.,0.,0.          $TVA0098
130.,197.,317.,370.,405.,447.,492.,539.,592.,0.,0.,0.        $TVA0099
140.,194.,312.,363.,397.,437.,479.,523.,572.,0.,0.,0.        $TVA0100
150.,193.,308.,358.,390.,428.,468.,510.,556.,606.,0.,0.      $TVA0101
160.,191.,305.,353.,384.,421.,459.,499.,542.,589.,0.,0.      $TVA0102
170.,190.,301.,348.,379.,414.,451.,489.,530.,574.,618.,0.    $TVA0103
180.,189.,298.,344.,374.,408.,443.,479.,518.,560.,601.,0.    $TVA0104
190.,187.,295.,340.,369.,401.,435.,470.,507.,546.,585.,626.  $TVA0105
200.,186.,293.,337.,365.,397.,430.,463.,499.,537.,574.,613.  $TVA0106
210.,186.,293.,[illegible],36[illegible],397.,4[illegible],462.,[illegible],536.,[illegible]  $TV[illegible]0107
220.,185.,290.,333.,361.,392.,424.,456.,490.,527.,562.,598.  $TVA0108
END
39      $  SPECIFIC VOLUME OF STEAM  -  FT**3/LBM
 130.00,157.34,132.00,149.66,134.00,142.42,136.00,135.58
 138.00,129.12,140.00,123.01,142.00,117.23,144.00,111.77
 146.00,106.60,148.00,101.71,150.00, 97.07,152.00, 92.68
 154.00, 88.52,156.00, 84.58,158.00, 80.84,160.00, 77.29
 162.00, 73.92,164.00, 70.73,166.00, 67.69,168.00, 64.80
 170.00, 62.06,172.00, 59.45,174.00, 56.97,176.00, 54.61
 178.00, 52.37,180.00, 50.23,182.00, 48.19,184.00, 46.25
 186.00, 44.40,188.00, 42.64,190.00, 40.96,192.00, 39.36
 194.00, 37.83,196.00, 36.37,198.00, 34.97,200.00, 33.64
 202.00, 32.37,204.00, 31.15,206.00, 29.99,208.00, 28.88,END
40      $  SATURATION PRESSURE OF STEAM  -  PSIA
 130.00,  2.22,132.00,  2.34,134.00,  2.47,136.00,  2.60
 138.00,  2.74,140.00,  2.89,142.00,  3.04,144.00,  3.20
 146.00,  3.36,148.00,  3.54,150.00,  3.72,152.00,  3.91
 154.00,  4.10,156.00,  4.31,158.00,  4.52,160.00,  4.74
 162.00,  4.97,164.00,  5.21,166.00,  5.46,168.00,  5.72
 170.00,  5.99,172.00,  6.72,174.00,  6.56,176.00,  6.87
 178.00,  7.18,180.00,  7.51,182.00,  7.85,184.00,  8.20
 186.00,  8.57,188.00,  8.95,190.00,  9.34,192.00,  9.75
 194.00, 10.17,196.00, 10.61,198.00, 11.06,200.00, 11.53
 202.00, 12.01,204.00, 12.51,206.00, 13.03,208.00, 13.57,END
41      $  CURRENT  -  AMPS  -  SYSTEM  1
0.,30.,3.1,30.,3.101,25.,6.2,25.,END
42      $  CURRENT  -  AMPS  -  SYSTEM  2
0.,0.,6.2,0.,END
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43      $  CURRENT  -  AMPS  -  SYSTEM  3
0.,0.,6.2,0.,END
44      $  PARTICAL PRESSURE OF WATER IN STACK  -  PSIA
   8,     0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90
 360.0, 27.0, 15.0,  8.0,  3.7,  1.6,  0.0,  0.0,   0.0
 380.0, 36.0, 21.0, 11.4,  5.6,  2.4,  1.0,  0.0,   0.0
 400.0, 47.0, 29.0, 16.0,  8.0,  3.4,  1.4,  0.0,   0.0
 420.0, 61.0, 38.0, 21.4, 10.8,  4.8,  1.9,  0.0,   0.0
 440.0, 79.0, 51.0, 29.0, 14.6,  6.6,  2.7,  1.0,   0.0
 460.0,102.0, 66.0, 38.0, 19.0,  8.9,  3.6,  1.3,   0.0
 480.0,128.0, 86.0, 50.0, 25.0, 11.9,  4.8,  1.7,   0.0
 500.0,160.0,104.0, 65.0, 32.5, 15.6,  6.3,  2.2,   0.0
 520.0,200.0,134.0, 83.0, 42.0, 20.6,  8.4,  3.0,   1.2
 540.0,250.0,170.0,104.0, 55.0, 27.5, 11.3,  4.2,   1.6
 560.0,310.0,210.0,130.0, 70.0, 36.0, 15.0,  5.9,   2.1
 580.0,380.0,260.0,160.0, 89.0, 46.0, 20.0,  8.0,   2.8
 600.0,470.0,320.0,195.0,113.0, 60.0, 27.0, 10.7,   3.7,END
45      $  ENTHALPY OF SUPERHEATED STEAM  -  BTU/LBM
   5,       126.08,  152.97,  170.06,  182.86,  193.21
 200.0,    1150.0,  1149.2,  1148.3,  1147.5,  1146.6
 220.0,    1159.1,  1158.5,  1157.7,  1157.0,  1156.2
 240.0,    1168.2,  1167.6,  1167.0,  1166.3,  1165.7
 260.0,    1177.3,  1176.8,  1176.3,  1175.7,  1175.1
 280.0,    1186.5,  1186.0,  1185.5,  1185.0,  1184.5
 300.0,    1195.6,  1195.2,  1194.7,  1194.3,  1193.9
 320.0,    1204.8,  1204.4,  1204.0,  1203.6,  1203.2
 340.0,    1213.9,  1213.6,  1213.2,  1212.9,  1212.5
 360.0,    1223.1,  1222.8,  1222.5,  1222.2,  1221.9
 380.0,    1232.3,  1232.1,  1231.8,  1231.5,  1231.2
 400.0,    1241.6,  1241.3,  1241.1,  1240.8,  1240.6,END
46,SPACE,1,END
47,SPACE,30,END
48,SPACE,30,END
49,SPACE,60,END     $ENTHALPY GLYCOL-WATER VS TEMP
50,SPACE,199,END     $SAVED TIME STEPS
51,SPACE,20,END    $RAD OUTLET TEMPS
52,SPACE,20,END
53,SPACE,20,END
54,SPACE,200,END     $SECONDARY REGEN COLD INLET TEMPS
55,SPACE,200,END
56,SPACE,200,END
57,SPACE,200,END     $SECONDARY BYPASS VALVE POSITION
58,SPACE,200,END
59,SPACE,200,END
60,SPACE,40,END    $GLYCOL OUTLET TEMPS FROM CONDENSER
61,SPACE,40,END
62,SPACE,40,END
63,SPACE,200,END     $SECONDARY REGEN HOT INLET TEMPS
64,SPACE,200,END
65,SPACE,200,END
66,SPACE,200,END     $SECONDARY REGEN GAINS, SYS 1
67,SPACE,200,END
68,SPACE,200,END
69,SPACE,200,END
70,SPACE,200,END     $SECONDARY REGEN GAINS, SYS 2
71,SPACE,200,END
72,SPACE,200,END
73,SPACE,200,END
74,SPACE,200,END     $SECONDARY REGEN GAINS, SYS 3
75,SPACE,200,END
76,SPACE,200,END
77,SPACE,200,END
78,SPACE,200,END     $SECONDARY REGEN COLD SIDE DELAYS
```

```
    79,SPACE,200,END
    80,SPACE,200,END
    81,SPACE,20,END      $SECONDARY REGEN HOT OUTLET TEMPS
    82,SPACE,20,END
    83,SPACE,20,END
    84          $ SYSTEM FLOW RATE VERSES RAD PRESS DROP
       0.,88.0,  5.,84.7, 10.,81.5, 15.,78.2, 20.,75.0, 25.,71.7
      30.,68.4, 35.,65.2, 40.,61.9, 45.,58.7, 50.,55.4, 55.,52.2
      60.,48.9, 65.,45.6, 70.,42.4, 75.,39.1, 80.,35.9, 85.,32.6
      90.,29.3, 95.,26.1,100.,22.8,105.,19.6,110.,16.3,115.,13.0
     120., 9.8,125., 6.5,130., 3.3,END
END
```

MAIN PROGRAM LISTING

```
       BCD 3EXECUTION
      COMMON/ALPHA/ WH2026(3)                                              F
      COMMON/BRAVO/QCOND(3), DMASS(3), WTH230(3)                           F
      COMMON/CHARLE/J,M,N                                                  F
      COMMON/DELTA/ INDEX1                                                 F
      COMMON/ECHO/ IPOINT                                                  F
      DIMENSION X(1000)                                                    F
      DIMENSION XK(1)                                                      F
      EQUIVALENCE (XK(1),K(1))                                             F
      NDIM=1000                                                            F
      NTH=0                                                                F
           SCLDEP(A4,K1) $SCALE VISCOSITY
           SPLIT(K2,A1+1,A5+1,A6+1) $SEPARATE DENSITY FROM TEMP
           ARYINV(K2,A6+1)          $INVERT DENSITY
           JOIN(K2,A5+1,A6+1,A1+1)  $ INVERSE DENSITY VS TEMP
           SPLIT(K2,A2+1,A5+1,A6+1) $SEPARATE CONDUCTIVITY FROM TEMP
           SPLIT(K2,A3+1,A5+1,A7+1) $SEPARATE SPECIFIC HEAT FROM TEMP
           DIVARY(K2,A6+1,A7+1,A7+1)$CONDUCTIVITY / SPECIFIC HEAT
           JOIN(K2,A5+1,A7+1,A21+1) $CONDUCTIVITY/SPECIFIC HEAT VS TEMP
           SPLIT(K2,A4+1,A5+1,A6+1) $SEPARATE VISCOSITY FROM TEMP
           ARYINV(K2,A6+1) $ INVERT VISCOSITY
           JOIN(K2,A5+1,A6+1,A4+1) $INVERSE VISCOSITY VS TEMP
           SPLIT(K916,A24+1,A47+1,A48+1)  $SEPARATE TEMP FROM ENTHALPY
           JOIN(K916,A48+1,A47+1,A49+1)  $ENTHALPY VS TEMP
       REM
       REM DATA ARRAY IS  NOW IN PROPER FORM FOR PROGRAM USAGE
       REM
       REM THE FOLLOWING INITIALIZES THE ENTIRE SOLID TEMPERATURE
       REM NETWORK TO COMPENSATE FOR VARYING INITIAL CONDITIONS. THE
       REM TEMPERATURE VALUE IS INPUT AS CONSTANT NUMBER K598.
           STFSQS(K598,K599,T701)
      IPOINT = 1                                                           F
      INDEX1 = 0                                                           F
      J = XK(398) + 0.0001                                                 F
      M = XK(399) + 0.0001                                                 F
      N = XK(400) + 0.0001                                                 F
      DO  100  I = J, M, N                                                 F
      WH2026(I) = (XK(I + 325)/XK(I + 328)) - XK(I + 325)                  F
  100 CONTINUE                                                             F
       REM*****BEGIN INITIALIZATION OF SECONDARY LOOP COMPONENTS*****
       REM FIRST INITIALIZE CONSTANT LOCATIONS
      DO 110 I=J,M,N                                                       F
       REM INITIALIZE SEC BP VLV STAT POS TO INITIAL DYNAMIC VALUE
      XK(I+456)=XK(I+374)                                                  F
      XK(I+365)=XK(I+331)                                                  F
      RTEST=XK(I+331)                                                      F
           D1DEG1(RTEST,A10,TTEST)
      XK(I+374)=TTEST                                                      F
      XK(I+381)=(1./XK(I+5))                                               F
       REM SET REG HOT INLET = COND GLY OUT
  110 XK(I+391)=XK(I+388)                                                  F
       REM SET REG COLD INLET = RAD OUTLET
           STFSQS(T618,1,K890)
           STFSQS(T636,1,K891)
           STFSQS(T654,1,K892)
       REM TIME STEP
           STFSQS(.002,K913,A50+1)
       REM NOW SOLVE SYSTEM IN STEADY STATE
      DO 300 I=J,M,N                                                       F
      IF(I-2) 120,130,140                                                  F
```

```
120       D3DEG1(K890,K896,K6,A38,RTEST)
          D1DEG1(K890,A3,STEST)
          D1DEG1(K896,A3,TTEST)
    GO TO 145                                                     F
130       D3DEG1(K891,K897,K7,A38,RTEST)
          D1DEG1(K891,A3,STEST)
          D1DEG1(K897,A3,TTEST)
    GO TO 145                                                     F
140       D3DEG1(K892,K898,K8,A38,RTEST)
          D1DEG1(K892,A3,STEST)
          D1DEG1(K898,A3,TTEST)
145 FLOWC=(1.-XK(I+374))*XK(I+5)                                  F
    UA=RTEST                                                      F
    CPC=STEST                                                     F
    CPH=TTEST                                                     F
    CC=FLOWC*CPC                                                  F
    CH=XK(I+5)*CPH                                                F
    BETA=CC/CH                                                    F
    RNTU=UA/CC                                                    F
    ET=EXP(-RNTU*(1.-BETA))                                       F
    EFF=(1.-ET)/(1.-BETA*ET)                                      F
    RTEST=1.-EFF                                                  F
    STEST=EFF                                                     F
    TTEST=EFF*BETA                                                F
    UTEST=1.-TTEST                                                F
    XK(I+377)=RTEST*XK(I+385) + STEST*XK(I+391)                   F
    XK(I+394)=TTEST*XK(I+385) + UTEST*XK(I+391)                   F
     IF(XK(I+374).GT.XK(381)) GO TO 147                           F
    VTEST=(1./FLOWC)*67.*XK(361)                                  F
    GO TO 150                                                     F
147 VTEST=1000.                                                   F
150 CONTINUE                                                      F
    IF(I-2) 155,160,165                                           F
155       STFSQS(RTEST,K912,A66+1)
          STFSQS(STEST,K912,A67+1)
          STFSQS(TTEST,K912,A68+1)
          STFSQS(UTEST,K912,A69+1)
          STFSQS(VTEST,K912,A78+1)
    GO TO 170                                                     F
160       STFSQS(RTEST,K912,A70+1)
          STFSQS(STEST,K912,A71+1)
          STFSQS(TTEST,K912,A72+1)
          STFSQS(UTEST,K912,A73+1)
          STFSQS(VTEST,K912,A79+1)
    GO TO 170                                                     F
165       STFSQS(RTEST,K912,A74+1)
          STFSQS(STEST,K912,A75+1)
          STFSQS(TTEST,K912,A76+1)
          STFSQS(UTEST,K912,A77+1)
          STFSQS(VTEST,K912,A80+1)
170 CONTINUE                                                      F
     REM INITIALIZE REMAINDER OF CONSTANTS
     REM COND GLY IN = REG COLD OUT
    XK(I+403)=XK(I+377)                                           F
     REM INITIALIZE REMAINING ARRAYS
    IF(I-2) 200,210,220                                           F
200       STFSQS(K890,K914,A51+1)    $RAD OUT
          STFSQS(K890,K912,A54+1)    $REG COLD IN
          STFSQS(K879,K912,A57+1)    $BP VLV FRAC
          STFSQS(K893,K915,A60+1)    $COND GLY OUT
          STFSQS(K893,K912,A63+1)    $REG HOT IN
          STFSQS(K899,K914,A81+1)    $REG HOT OUT
    GO TO 230                                                     F
```

```
210       STFSQS(K891,K914,A52+1)
          STFSQS(K891,K912,A55+1)
          STFSQS(K880,K912,A58+1)
          STFSQS(K894,K915,A61+1)
          STFSQS(K894,K912,A64+1)
          STFSQS(K900,K914,A82+1)
     GO TO 230                                                           F
220       STFSQS(K892,K914,A53+1)
          STFSQS(K892,K912,A56+1)
          STFSQS(K881,K912,A59+1)
          STFSQS(K895,K915,A62+1)
          STFSQS(K895,K912,A65+1)
          STFSQS(K901,K914,A83+1)
230  CONTINUE                                                            F
      REM  END OF INITIALIZATION LOOP*********************
300  CONTINUE                                                            F
          VARBL2  $  ANALYZE PRESSURE NETWORK AND OBTAIN FLOW RATES
          CNFRWD  $ PERFORM TRANSIENT ANALYSIS
      END
      BCD 3VARIABLES 1
     COMMON/ALPHA/ WH2O26(3)                                             F
     COMMON/BRAVO/QCOND(3),DMASS(3),WTH230(3)                            F
     COMMON/CHARLE/J,M,N                                                 F
     COMMON/FOXTRT/ PCKOH(3)                                             F
     DIMENSION SVOL11(3),WH2O2P(3),PRES31(3),SVOL31(3),                  F
    1          WH2O30(3),SVOL21(3),DSPVOL(3),SFCH2(3),SFCO2(3),          F
    2          QGENAT(3),QH2(3),QO2(3),QELECT(3),PARPH2(3),SVOL32(3),    F
    3          WDTCP2(3),QRS(3),QSTORD(3),SVOL12(3), QSM(3),             F
    4          QREACT(3), QH2O(3), QOUT(3), QIN(3), DELTAQ(3),           F
    5          TSKIN1(3),DTEMP(3),TSKIN2(3), WH2O20(3), DIFF(3),         F
    6          WDTCP1(3), WH2O25(3)                                      F
     DIMENSION XK(1)                                                     F
     EQUIVALENCE (XK(1),K(1))                                            F
      REM INTERPOLATE DO LOOP INDEX ARRAYS
          D1DEG1(TIMEN,A26,K902)                $ J
          D1DEG1(TIMEN,A27,K903)                $ M
          D1DEG1(TIMEN,A28,K904)                $ N
      REM CHANGE INDICES FROM FLOATING POINT TO INTEGER
          FIX(K902,K26)     $    J
          FIX(K903,K28)     $    M
          FIX(K904,K32)     $    N
     J=K(26)                                                             F
     M=K(28)                                                             F
     N=K(32)                                                             F
     DO  667  I = 1,3                                                    F
667  XK(I + 469) = XK(I + 5)                                             F
     DO  668  I = 1, 3                                                   F
668  XK(I + 5) = 0.0001                                                  F
     DO  669  I = J, M, N                                                F
669  XK(I + 5) = XK(I + 469)                                             F
          D1DEG1(TIMEN,A41,K854)                $ SYSTEM 1
          D1DEG1(TIMEN,A42,K855)                $ SYSTEM 2
          D1DEG1(TIMEN,A43,K856)                $ SYSTEM 3
     DO  500  I = J, M, N                                                F
     DT = 10.                                                            F
     IF (I - 2) 1, 2, 3                                                  F
  1       D1DEG2(K836, A39, K920)
          D1DEG2(K836, A40, K932)
     GO TO 4                                                             F
  2       D1DEG2(K837, A39, K921)
          D1DEG2(K837, A40, K933)
     GO TO 4                                                             F
  3       D1DEG2(K838,A39,K922)
          D1DEG2(K838, A40, K934)
```

```
    4 CONTINUE                                                          F
      SVOL11(I) = XK(I+415)                                             F
      DRATE = 0.05                                                      F
      IOLD = 1                                                          F
      DO  90  JJ = 1, 100                                               F
      WH2O2P(I) = XK(349)*XK(I+349)*DTIMEU                              F
      WH2O25(I) = WH2O26(I) + XK(I + 345)*WH2O2P(I)                     F
      PCKOH(I) = XK(I+325)/(XK(I+325) + WH2O25(I))                      F
      XK(I+424) = PCKOH(I)                                              F
      IF (I - 2) 21, 22, 23                                             F
   21       D2DEG2(K929, K847, A44, K926)
      GO TO 24                                                          F
   22       D2DEG2(K930, K848, A44, K927)
      GO TO 24                                                          F
   23       D2DEG2(K931,K849,A44,K928)
   24 CONTINUE                                                          F
      PRES31(I) = XK(I+421)                                             F
      SVOL31(I) = (XK(335)*(XK(I+342)+460.))/(PRES31(I)*144.)           F
      DMASS(I) = (1.0-XK(I+345))*WH2O2P(I)                              F
      WH2O30(I) =  XK(I+336)*DTIMEU/SVOL31(I)                           F
      WH2O20(I) = WH2O30(I) - DMASS(I)                                  F
      SVOL21(I) = XK(I+336)*DTIMEU/WH2O20(I)                            F
      DSPVOL(I) = SVOL11(I) - SVOL21(I)                                 F
      IF (ABS(DSPVOL(I)) - XK(353))  100, 100, 35                       F
   35 IF (DSPVOL(I))  45, 100, 50                                       F
   45 IMULT = 1                                                         F
      INEW = IOLD                                                       F
      IOLD = -1                                                         F
      GO TO 60                                                          F
   50 IMULT = -1                                                        F
      INEW = IOLD                                                       F
      IOLD = 1                                                          F
   60 XK(I + 345) = XK(I + 345) + DRATE*IMULT                           F
      IF (INEW - IOLD)  70, 90, 70                                      F
   70 DRATE = DRATE/2.0                                                 F
   90 CONTINUE                                                          F
      WRITE (6, 95)                                                     F
   95 FORMAT ( 79H ITERATIVE SCHEME DID NOT FIND A SOLUTION WITHIN SPECIF
     1FIED NUMBER OF ITERATIONS)                                        F
  100 CONTINUE                                                          F
      WH2O26(I) = WH2O25(I)
      XK(I+353) = 5.5[illegible]3364 - 1.[illegible]39*XK(I+[illegible])
     1 +2.654927E-3*XK(I+349)**2 - 1.33[illegible]E-[illegible]*XK(I+34[illegible])**
     2 +9.69469E-2*XK(I+342) + 4.686233E-[illegible]*XK(I+349)*XK(I+ 42)  F
     3 - 3.573639E-7*XK(I+349)**2*XK(I+342) - 1.525995E-5*XK(I+342)**2  F
     4 -4.889387E-6*XK(I+349)*XK(I+342)**2 - 1.292758E-7*XK(I+342)**3   F
      XK(I + 353) = XK(I + 353) - 24.1*(.75 - PCKOH(I))                 F
      XK(I + 412) = XK(I + 349)*XK(I + 353)                             F
      SFCH2(I) = 8.292E-5*31.*XK(I+349)                                 F
      SFCO2(I) = 7.94*SFCH2(I)                                          F
      QGENAT(I) = 51600.*SFCH2(I)                                       F
      QH2(I) = SFCH2(I)*3.43*(XK(I + 342) - XK(I + 463))                F
      QO2(I) = SFCO2(I)*0.219*(XK(I + 342) - XK(I + 466))               F
      QELECT(I) = 3.41276*XK(I+349)*XK(I+353)                           F
      PARPH2(I) = 60. - PRES31(I)                                       F
      SVOL32(I) = (XK(336)*(XK(I + 342) + 460.))/(PARPH2(I)*144.)       F
      WDTCP1(I) =  (XK(I+336)/SVOL31(I))*0.445                          F
      WDTCP2(I) =  (XK(I+336)/SVOL32(I))*3.48                           F
      QRS(I) = (WDTCP1(I)+WDTCP2(I))*(XK(I+342)-XK(I+339))              F
      QSM(I) = 3.25*XK(I + 342) - 1.6*XK(I + 439) - 882.                F
      QSTORD(I) = QGENAT(I) - QH2(I) - QO2(I) - QELECT(I) - QRS(I) -    F
     1 QSM(I)                                                           F
      XK(I+342) = XK(I+342) + (QSTORD(I)*DTIMEU)/XK(358)                F
```

```
      SVOL12(I) = (XK(336)*(XK(I+331)+460.))/(PARPH2(I)*144.)                F
      WTH230(I) = (XK(I+336)/SVOL12(I)-XK(I+349)*XK(443))*DTIMEU             F
      QREACT(I) = (XK(445)*DMASS(I))/DTIMEU +                                F
     1            XK(444)*(XK(I + 349)*XK(349) - DMASS(I)/DTIMEU)            F
      QH2O(I) = (DMASS(I)*(XK(I + 331) - XK(I + 439))*1.0)/DTIMEU            F
      CONST1 = 3.44*WTH230(I)/DTIMEU+XK(I+336)/XK(I+415)*1.0                 F
     1        + DMASS(I)*1.0/DTIMEU                                          F
      CONST2 = 1160.*DMASS(I)/DTIMEU                                         F
      CONST3 = ((XK(I+336)/SVOL12(I))*3.44+(XK(I+336)/SVOL11(I))*1.0)/       F
     1        ((WTH230(I)/DTIMEU)*3.44+(WH2030(I)/DTIMEU)*1.0)               F
      CONST4 = -1.2*XK(I + 342) + 882.                                       F
  150 XK(I + 371) = XK(I + 342) - (XK(I + 339) - XK(I + 331))*CONST3         F
      QCOND(I) = (XK(I + 371) - XK(I + 331))*CONST1 + CONST2                 F
      QOUT(I) = QREACT(I)                                                    F
      QIN(I) = QCOND(I) + QH2O(I) + QELECT(I) + QSM(I) + QSTORD(I)           F
      DELTAQ(I) = QOUT(I) - QIN(I)                                           F
      IF (ABS(DELTAQ(I)) - XK(449))  180, 180, 160                           F
  160 IF (ABS(CONST4 - XK(I + 339)) - XK(450))  180, 180, 165                F
  165 IF (ABS(CONST4 - CONST5) - ABS(CONST4 - XK(I + 339)))  168,168,170F
  168 DT = -DT/2.                                                            F
  170 CONST5 = XK(I + 339)                                                   F
      XK(I + 339) = XK(I + 339) + DT                                         F
      GO TO 150                                                              F
  180 CONTINUE                                                               F
      XK(I+450) = DMASS(I)/DTIMEU                                            F
      XK(I+453) = XK(I+345)*100.                                             F
  500 CONTINUE                                                               F
       REM INTERPOLATE BYPASS OPTION ARRAY
           D1DEG1(TIMEN,A35,K905)                    $ SYSTEM 1
           D1DEG1(TIMEN,A36,K906)                    $ SYSTEM 2
           D1DEG1(TIMEN,A37,K907)                    $ SYSTEM 3
       REM CHANGE BYPASS FROM FLOATING POINT TO INTEGER
           FIX(K905,K9)        $  SYSTEM 1
           FIX(K906,K10)       $  SYSTEM 2
           FIX(K907,K11)       $  SYSTEM 3
       REM INTERPOLATE HEAT FLUX ARRAYS
      RTEST = TIMEM                                                          F
      IF(TIMEM.GE.1.55) RTEST = TIMEM - 1.55*FLOAT(IFIX(TIMEM/1.55))         F
           D11CYL(K600,RTEST,A13,K12)      $  PANEL 1
           D11CYL(K600,RTEST,A14,K13)      $  PANEL 2
           D11CYL(K600,RTEST,A15,K14)      $  PANEL 3
           D11CYL(K600,RTEST,A16,K15)      $  PANEL 4
           D11CYL(K600,RTEST,A17,K16)      $  PANEL 5
           D11CYL(K600,RTEST,A18,K17)      $  PANEL 6
           D11CYL(K600,RTEST,A19,K18)      $  PANEL 7
           D11CYL(K600,RTEST,A20,K19)      $  PANEL 8
       REM APPLY INCIDENT  HEAT
       REM
           ARYMPY(K20,A12+1,K12,Q701) $PANEL 1
           ARYMPY(K20,A12+1,K13,Q725) $PANEL 2
           ARYMPY(K20,A12+1,K14,Q749) $PANEL 3
           ARYMPY(K20,A12+1,K15,Q773) $PANEL 4
           ARYMPY(K20,A12+1,K16,Q797) $PANEL 5
           ARYMPY(K20,A12+1,K17,Q821) $PANEL 6
           ARYMPY(K20,A12+1,K18,Q845) $PANEL 7
           ARYMPY(K20,A12+1,K19,Q869) $PANEL 8
       REM
       REM BUILD A TEMPERATURE ARRAY TO EVALUATE THERMAL FLUID FLOW COND
       REM
           BLDARY(A9+1,T601,T602,T603,T604,T605,T606,T607,T608,T609
                       T610,T611,T612,T613,T614,T615,T616,T617,T611
                       T619,T620,T621,T622,T623,T624,T625,T626,T627)
          BLDARY(A9+28,T628,T629,T630,T631,T632,T633,T634,T635,T629
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```
                T637,T638,T639,T640,T641,T642,T643,T644,T645
                T646,T647,T648,T649,T650,T651,T652,T653,T647)
   REM
   REM
   REM EVALUATE CONVECTION CONDUCTORS
   REM
   REM EVALUATE GR NUMBER
        D1D1MI(K22,A9+2,A21,K805,G1001)  $SYSTEM 1
        D1D1MI(K22,A9+20,A21,K805,G1017) $SYSTEM 2
        D1D1MI(K22,A9+38,A21,K805,G1033) $SYSTEM 3
        ARYMPY(K22,G1001,K821,G1001)     $SYSTEM 1
        ARYMPY(K22,G1017,K822,G1017)     $SYSTEM 2
        ARYMPY(K22,G1033,K823,G1033)     $SYSTEM 3
  DO 40 I=12,59                                                    F
40 G(I)=46.1235+(.19533/(G(I)+.015*(G(I)**.33333333)))             F
        D1D1MI(K22,A9+2,A2,G1001,G1001)  $SYSTEM 1
        D1D1MI(K22,A9+20,A2,G1017,G1017) $SYSTEM 2
        D1D1MI(K22,A9+38,A2,G1033,G1033) $SYSTEM 3
   REM
   REM EVALUATE FLUID FLOW CONDUCTORS - G= W*C
   REM
        D1D1IM(K24,A9+1,A3,K6,G601)    $SYSTEM 1
        D1D1IM(K24,A9+19,A3,K7,G619)   $SYSTEM 2
        D1D1IM(K24,A9+37,A3,K8,G637)   $SYSTEM 3
  IF(K(9)) 10,10,11                                                F
10  G(158) = 0.                                                    F
  GO TO 12                                                         F
11 CONTINUE                                                        F
        STFSQS(K594,K595,G611)
12 IF(K(10)) 13,13,14                                              F
13  G(176) = 0.                                                    F
  GO TO 15                                                         F
14 CONTINUE                                                        F
        STFSQS(K594,K595,G629)
15 IF(K(11)) 16,16,17                                              F
16  G(194) = 0.                                                    F
  GO TO 18                                                         F
17 CONTINUE                                                        F
        STFSQS(K594,K595,G647)
18 CONTINUE                                                        F
   END
   BCD 3VARIABLES 2
  COMMON/BRAVO/QCOND(3),DMASS(3),WTH230(3)                         F
  COMMON/CHARLE/ J, M, N                                           F
  COMMON/DELTA/ INDEX1                                             F
  DIMENSION XK(1)                                                  F
  EQUIVALENCE (XK(1),K(1))                                         F
   REM BUILD A TEMPERATURE ARRAY FOR USE IN COMPUTING CONDUCTANCES
        BLDARY(A8+1,T601,T602,T603,T603,T604,T605,T605,T606,T607
                T607,T608,T609,T609,T610,T611,T611,T612,T613
                T613,T614,T615,T615,T616,T617,T617,T618,T611)
        BLDARY(A8+28,T619,T620,T621,T621,T622,T623,T623,T624,T625
                T625,T626,T627,T627,T628,T629,T629,T630,T631
                T631,T632,T633,T633,T634,T635,T635,T636,T629)
        BLDARY(A8+55,T637,T638,T639,T639,T640,T641,T641,T642,T643
                T643,T644,T645,T645,T646,T647,T647,T648,T649
                T649,T650,T651,T651,T642,T653,T653,T654,T647)
   REM COMPUTE REYNOLDS NUMBERS
        D1D1MI(A8,A8+1,A4,K601,A22+1) $ (4/(P*VIS))
        ARYMPY(K5,A22+1,K6,A22+1)     $ RE FOR SYSTEM 1
        ARYMPY(K5,A22+28,K7,A22+28)   $ RE FOR SYSTEM 2
        ARYMPY(K5,A22+55,K8,A22+55)   $ RE FOR SYSTEM 3
   REM COMPUTE (8*WP*L)/((A**3)*(DENSITY))
        D1D1MI(A8,A8+1,A1,K501,G501)
```

```
      REM COMPUTE (K-FACTOR)/(2*DENSITY*(A**2))
          DIDIMI(A8,A8+1,A1,K701,A23+1)
          DIVARY(A23,G501,A22+1,G501)
          ADDARY(A23,A23+1,G501,G501)
      REM - ALL CONSTANTS FOR PRESSURE DROP HAVE BEEN COMPUTED -- SUM
      REM FOR RESPECTIVE SYSTEMS AND SOLVE FOR DELP
      REM
      REM  IN THE FOLLOWING SYSTEMS COMPRESSIONS A FLAG HAS BEEN SET
      REM  TO INDICATE FLOW DIRECTION THROUGH THE BYPASS VALVES -- THE
      REM  SYSTEM CONDUCTANCE IS CALCULATED ACCORDINGLY
      REM     FLAG FOR SYSTEM 1 = K9 (0-RADIATOR , 1-BYPASS)
      REM     FLAG FOR SYSTEM 2 = K10(0-RADIATOR , 1-BYPASS)
      REM     FLAG FOR SYSTEM 3 = K11(0-RADIATOR , 1-BYPASS)
      REM
      REM COMPRESS PRESSURE NETWORK FOR SYSTEM 1
      REM
          SUMARY(K3,G501,K582)
          SUMARY(K4,G516,K583)
     IF(K(9).EQ.0) K(117)=K(116)                                         F
     IF(K(9).EQ.1)XK(117)=G(86)                                          F
          ADD(K582,K584,G526,K585)
      REM
      REM COMPRESS PRESSURE NETWORK FOR SYSTEM 2
      REM
          SUMARY(K3,G528,K586)
          SUMARY(K4,G543,K587)
     IF(K(10).EQ.0) K(121)=K(120)                                        F
     IF(K(10).EQ.1)XK(121)=G(113)                                        F
          ADD(K586,K588,G553,K589)
      REM
      REM COMPRESS PRESSURE NETWORK FOR SYSTEM 3
      REM
          SUMARY(K3,G555,K590)
          SUMARY(K4,G570,K591)
     IF(K(11).EQ.0) K(125)=K(124)                                        F
     IF(K(11).EQ.1)XK(125)=G(140)                                        F
          ADD(K590,K592,G580,K593)
          SCALE(K25,K585,K585,K589,K589,K593,K593)
          ARINDV(3,K6,1.,K821) $INVERT FLOW RATES
      REM  SAVE TIME STEP
      REM FIRST TIME STEP, DTIMEU=0., SO DON'T STORE IT
     IF(DTIMEU.EQ.0.) GO TO 5                                            F
          SLPARY(DTIMEU,A50)
   5 CONTINUE                                                            F
     DO 700 I=J,M,N                                                      F
     IF(I-2) 10,11,12                                                    F
  10      SLPARY(T618,A51)
          DIDEGI(T618,A1,RTEST)
          MLTPLY(K821,RTEST,K864,TTEST)
          DELAY1(A50,A51,TTEST,K890,ITEST)
          SLPARY(K890,A54)
          ARYSTO(K912,VTEST,A57+1)
     GO TO 13                                                            F
  11      SLPARY(T636,A52)
          DIDEG1(T636,A1,RTEST)
          MLTPLY(K822,RTEST,K864,TTEST)
          DELAY1(A50,A52,TTEST,K891,ITEST)
          SLPARY(K891,A55)
          ARYSTO(K912,VTEST,A58+1)
     GO TO 13                                                            F
  12      SLPARY(T654,A53)
          DIDEG1(T654,A1,RTEST)
          MLTPLY(K823,RTEST,K864,TTEST)
```

```
        DELAY1(A50,A53,TTEST,K892,ITEST)
        SLPARY(K892,A56)
        ARYSTO(K912,VTEST,A59+1)
13 CONTINUE                                                          F
    REM  DETERMINE BYPASSED FRACTION
   RTEST=XK(I+331)                                                   F
   STEST=XK(I+365)                                                   F
   VTEST = XK(I+456)                                                 F
   IF(K(I+368)) 20,30,30                                             F
20 IF(RTEST.LE.STEST) GO TO 35                                       F
25      DIDEG1(RTEST,A10,UTEST)
   IF(UTEST.LE.VTEST)  GO TO 39                                      F
   K(I+368)= 1                                                       F
        DIDEG1(RTEST,A10,UTEST)
   VTEST=UTEST                                                       F
   GO TO 39                                                          F
30 IF(RTEST.GE.STEST) GO TO 25                                       F
35      DIDEG1(RTEST,A11,UTEST)
   IF(UTEST.GE.VTEST)  GO TO 39                                      F
   K(I+368)= -1                                                      F
        DIDEG1(RTEST,A11,UTEST)
   VTEST=UTEST                                                       F
39 CONTINUE                                                          F
   XK(I+456) = VTEST                                                 F
   IF(I-2) 40,41,42                                                  F
40      SLPARY(VTEST,A57)
        CNVLTN(A50,A57,0,2,K879)
   GO TO 43                                                          F
41      SLPARY(VTEST,A58)
        CNVLTN(A50,A58,0,2,K880)
   GO TO 43                                                          F
42      SLPARY(VTEST,A59)
        CNVLTN(A50,A59,0,2,K881)
43 CONTINUE                                                          F
    REM  DETERMINE COLD SIDE REGENERATOR FLOW
   FLORGC = (1.-XK(I+374))*XK(I+5)                                   F
    REM  DETERMINE REGENERATOR COLD SIDE DELAY
    REM IF BP FRACTION IS LARGE, SET FLORGC TO A SMALL FINITE VALUE
   IF(XK(I+374).GT.XK(381)) FLORGC=(1.-XK(381))*XK(I+5)              F
   TTEST=(XK(I+385) + XK(I+377))/2.                                  F
        DIDEG1(TTEST,A1,RTEST)
   TTEST=XK(385)*(1./FLORGC)*RTEST*XK(361)                           F
    REM SLIDE DELAY INTO ARRAY AND DETERMINE DELAY, COND. OUTLET TO
    REM REGEN HOT INLET
   IF(I-2) 70,80,90                                                  F
70      SLPARY(TTEST,A78)
        DIDEG1(K893,A1,RTEST)
        MLTPLY(K821,RTEST,K867,TTEST)
   TTEST=TTEST-DTIMEU                                                F
    REM DELAY1(A50,A60,TTEST,K896,ITEST)  DELETED DUE TO INSTABILITY
        CNVLTN(A50,A60,0,2,K896)
   XK(392) = XK(392) + 460.                                          F
   XK(464) = XK(460) + (XK(392) - XK(460))*(.53 + .002*XK(6) + .018* F
  1 XK(462))                                                         F
   DH = (XK(460) - XK(464))*(.152 + .0000225*(XK(464) + XK(460)))    F
  1 *XK(462)/XK(6)                                                   F
   X = 116440.5 + 2401.364*DH + XK(392)*(682.4676 + XK(392))         F
   TOW = SQRT(X) - 341.2338                                          F
   XK(467) = XK(461) + .75*(TOW - XK(461))                           F
   DH = (XK(461) - XK(467))*3.47*XK(463)/XK(6)                       F
   X = 116440.5 + 2401.364*DH + TOW*(682.4676 + TOW)                 F
   XK(392) = SQRT(X) - 341.2338 - 460.                               F
   XK(464) = XK(464) - 460.                                          F
   XK(467) = XK(467) - 460.                                          F
```

```
        SLPARY(K896,A63)
   GO TO 100                                                           F
 80     SLPARY(TTEST,A79)
        D1DEG1(K894,A1,RTEST)
        MLTPLY(K822,RTEST,K867,TTEST)
   TTEST=TTEST-DTIMEU                                                  F
    REM DELAY1(A50,A61,TTEST,K897,ITEST)  DELETED DUE TO INSTABILITY
        CNVLTN(A50,A61,0,2,K897)
   XK(393) = XK(393) + 460.                                            F
   XK(465) = XK(460) + (XK(393) - XK(460))*(.53 + .002*XK(7) + .018*   F
  1 XK(462))                                                           F
   DH = (XK(460) - XK(465))*(.152 + .0000225*(XK(465) + XK(460)))      F
  1 *XK(462)/XK(7)                                                     F
   X = 116440.5 + 2401.364*DH + XK(393)*(682.4676 + XK(393))           F
   TOW = SQRT(X) - 341.2338                                            F
   XK(468) = XK(461) + .75*(TOW - XK(461))                             F
   DH = (XK(461) - XK(468))*3.47*XK(463)/XK(7)                         F
   X = 116440.5 + 2401.364*DH + TOW*(682.4676 + TOW)                   F
   XK(393) = SQRT(X) - 341.2338 - 460.                                 F
   XK(465) = XK(465) - 460.                                            F
   XK(468) = XK(468) - 460.                                            F
        SLPARY(K897,A64)
   GO TO 100                                                           F
 90     SLPARY(TTEST,A80)
        D1DEG1(K895,A1,RTEST)
        MLTPLY(K823,RTEST,K867,TTEST)
   TTEST=TTEST-DTIMEU                                                  F
    REM DELAY1(A50,A62,TTEST,K898,ITEST)  DELETED DUE TO INSTABILITY
        CNVLTN(A50,A62,0,2,K898)
   XK(394) = XK(394) + 460.                                            F
   XK(466) = XK(460) + (XK(394) - XK(460))*(.53 + .002*XK(8) + .018*   F
  1 XK(462))                                                           F
   DH = (XK(460) - XK(466))*(.152 + .0000225*(XK(466) + XK(460)))      F
  1 *XK(462)/XK(8)                                                     F
   X = 116440.5 + 2401.364*DH + XK(394)*(682.4676 + XK(394))           F
   TOW = SQRT(X) - 341.2338                                            F
   XK(469) = XK(461) + .75*(TOW - XK(461))                             F
   DH = (XK(461) - XK(469))*3.47*XK(463)/XK(8)                         F
   X = 116440.5 + 2401.364*DH + TOW*(682.4676 + TOW)                   F
   XK(394) = SQRT(X) - 341.2338 - 460.                                 F
   XK(466) = XK(466) - 460.                                            F
   XK(469) = XK(469) - 460.                                            F
        SLPARY(K898,A65)
100 CONTINUE                                                           F
    REM  COMPUTE REGEN HOT SIDE DELAY
   TTEST=(XK(I+394) + XK(I+391))/2.                                    F
        D1DEG1(TTEST,A1,RTEST)
   XK(33)=XK(385)*XK(I+316)*RTEST*XK(364)                              F
    REM  FIND TERMINAL ENTHALPIES AND UA OF EACH REGENERATOR
   IF(I-2) 110,120,130                                                 F
110     D3DEG1(K890,K896,K6,A38,RTEST)        $UA
        D1DEG1(K896,A24,STEST)                $HH1
        D1DEG1(K899,A24,TTEST)                $HH2
        D1DEG1(K890,A24,UTEST)                $HC1
        D1DEG1(K882,A24,VTEST)                $HC2
   GO TO 140                                                           F
120     D3DEG1(K891,K897,K7,A38,RTEST)        $UA
        D1DEG1(K897,A24,STEST)                $HH1
        D1DEG1(K900,A24,TTEST)                $HH2
        D1DEG1(K891,A24,UTEST)                $HC1
        D1DEG1(K883,A24,VTEST)                $HC2
   GO TO 140                                                           F
```


F

```
130       D3DFG1(K892,K898,K8,A38,RTEST)       $UA
          D1DEG1(K898,A24,STEST)               $HH1
          D1DEG1(K901,A24,TTEST)               $HH2
          D1DEG1(K892,A24,UTEST)               $HC1
          D1DEG1(K884,A24,VTEST)               $HC2
140 CONTINUE                                                      F
     REM  COMPUTE TEMPERATURE AND ENTHALPY DROPS ON EACH SIDE
    UA=RTEST                                                      F
    HH1=STEST                                                     F
    HH2=TTEST                                                     F
    HC1=UTEST                                                     F
    HC2=VTEST                                                     F
    DHH=ABS(HH1-HH2)                                              F
    DHC=ABS(HC1-HC2)                                              F
    DTH=ABS(XK(I+391)-XK(I+394))                                  F
    DTC=ABS(XK(I+385)-XK(I+377))                                  F
    CC=FLORGC*(1./DTC)*DHC                                        F
    CH=XK(I+5)*(1./DTH)*DHH                                       F
    BETA=CC/CH                                                    F
    RNTU=UA/CC                                                    F
    ET=EXP(-RNTU*(1.-BETA))                                       F
    EFF=(1.-ET)/(1.-BETA*ET)                                      F
     REM  COMPUTE REGEN GAINS BASED ON REGEN INLET CONDITIONS
    RTEST=1.-EFF                                                  F
    STEST=EFF                                                     F
    TTEST=EFF*BETA                                                F
    UTEST=1.-TTEST                                                F
     REM  SLIDE GAIN CONSTANTS INTO ARRAYS AND
     REM  DETERMINE TRANSIENT OUTLET TEMPS
    IF(I-2) 150,160,170                                           F
150       SLPARY(RTEST,A66)  $SYSTEM 1
          SLPARY(STEST,A67)
          SLPARY(TTEST,A68)
          SLPARY(UTEST,A69)
          DELAY2(A50,A54,A78,VTEST,JTEST)
          CNVLTE(A50,A54,A66,JTEST,1,RTEST)    $OUTPUT T11
          CNVLTE(A50,A63,A67,0,1,STEST)        $OUTPUT T12
          DELAY1(A50,A63,K33,VTEST,JTEST)
          CNVLTE(A50,A54,A68,0,1,TTEST)        $OUTPUT T21
          CNVLTE(A50,A63,A69,JTEST,1,UTEST)    $OUTPUT T22
    VTEST=TTEST+UTEST                                             F
          SLPARY(VTEST, A81)
    GO TO 180                                                     F
160       SLPARY(RTEST,A70)
          SLPARY(STEST,A71)
          SLPARY(TTEST,A72)
          SLPARY(UTEST,A73)
          DELAY2(A50,A55,A79,VTEST,JTEST)
          CNVLTE(A50,A55,A70,JTEST,1,RTEST)    $OUTPUT T11
          CNVLTE(A50,A64,A71,0,1,STEST)        $OUTPUT T12
          DELAY1(A50,A64,K33,VTEST,JTEST)
          CNVLTE(A50,A55,A72,0,1,TTEST)        $OUTPUT T21
          CNVLTE(A50,A64,A73,JTEST,1,UTEST)    $OUTPUT T22
    VTEST=TTEST + UTEST                                           F
          SLPARY(VTEST,A82)
    GO TO 180                                                     F
170       SLPARY(RTEST,A74)  $SYSTEM 3
          SLPARY(STEST,A75)
          SLPARY(TTEST,A76)
          SLPARY(UTEST,A77)
          DELAY2(A50,A56,A80,VTEST,JTEST)
          CNVLTE(A50,A56,A74,JTEST,1,RTEST)    $OUTPUT T11
          CNVLTE(A50,A65,A75,0,1,STEST)        $OUTPUT T12
          DELAY1(A50,A65,K33,VTEST,JTEST)
```

```
        CNVLTE(A50,A56,A76,0,1,TTEST)         $OUTPUT T21
        CNVLTE(A50,A65,A77,JTEST,1,UTEST)     $OUTPUT T22
    VTEST=TTEST + UTEST                                                 F
        SLPARY(VTEST,A83)
     REM  COLD + HOT TRANSIENT OUTLET TEMPS
180 XK(I+377)=RTEST + STEST                                             F
    XK(I+394)=TTEST + UTEST                                             F
    TTEST = (XK(I + 391) + XK(I + 394))/2.                              F
        D1DEG1(TTEST,A3,UTEST)                  $  SEC REG HOT CP
    TTEST = (XK(I + 377) + XK(I + 385))/2.                              F
        D1DEG1(TTEST,A3,VTEST)                  $  SEC REG COLD CP
    XK(I + 377) = XK(I + 385) + ((XK(I + 391) - XK(I + 394))*UTEST)/   F
   1  ((1. - XK(I + 374))*VTEST)                                        F
    IF (XK(I + 377).GT.XK(I + 391))  XK(I + 377) = XK(I + 391)          F
    XK(I + 377) = (XK(I + 377) + XK(I + 322))/2.                        F
    XK(I + 322) = XK(I + 377)                                           F
     REM  COMPUTE DELAY TO RAD INLET AND SET RAD INLET TEMP
    IF(I-2) 190,200,210                                                 F
190     D1DEG1(K899,A1,RTEST)
        MLTPLY(K821,RTEST,K869,TTEST)
        DELAY1(A50,A81,TTEST,T601,ITEST)
    GO TO 220                                                           F
200     D1DEG1(K900,A1,RTEST)
        MLTPLY(K822,RTEST,K869,TTEST)
        DELAY1(A50,A82,TTEST,T619,ITEST)
    GO TO 220                                                           F
210     D1DEG1(K901,A1,RTEST)
        MLTPLY(K823,RTEST,K869,TTEST)
        DELAY1(A50,A83,TTEST,T637,ITEST)
220 CONTINUE                                                            F
     REM  COMPUTE CONDENSER INLET TEMP
    IF(XK(I+374).GT.XK(381)) GO TO 290                                  F
    RTEST=XK(I+385)                                                     F
    STEST=XK(I+377)                                                     F
        D1DEG1(RTEST,A24,TTEST)       $ENTHALPY BYPASS
        D1DEG1(STEST,A24,UTEST)       $REGEN ENTHALPY
260 VTEST=TTEST*XK(I+374) + UTEST*(1.-XK(I+374))                        F
        D1DEG1(VTEST,A49,RTEST)       $TEMP OUT OF VALVE
    XK(I+403)=RTEST                                                     F
    GO TO 300                                                           F
290 XK(I+403)=XK(I+385)                                                 F
300 CONTINUE                                                            F
    IF (INDEX1) 450, 450, 301                                           F
301  INDEX2 = 1                                                         F
    DTEMP=XK(447)                                                       F
    ISGN=K(448)                                                         F
    XK(I + 365) = XK(I + 331)                                           F
310 T2OLD=XK(I+331)                                                     F
    T4OLD=XK(I+388)                                                     F
    IF(I-2) 320,330,340                                                 F
320     D1DEG1(K908,A24,RTEST)
        D1DEG1(K893,A24,STEST)
    GO TO 350                                                           F
330     D1DEG1(K909,A24,RTEST)
        D1DEG1(K894,A24,STEST)
    GO TO 350                                                           F
340     D1DEG1(K910,A24,RTEST)
        D1DEG1(K895,A24,STEST)
350 CONTINUE                                                            F
    IF (INDEX2 - 100)  354, 354, 445                                    F
354  QGLY = XK(I + 5)*(STEST - RTEST)                                   F
    DTGAS=XK(I+371)-XK(I+331)                                           F
351  QGAS = DTGAS*(3.44*WTH230(I)/DTIMEU + XK(I + 336)/XK(I + 415)*1.0)F
   1      +(DMASS(I)*1160.+DMASS(I)*DTGAS*1.0)/DTIMEU                   F
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352  XK(I + 331) = XK(I + 388) - XK(I + 316)*(49.2287949 +             F
    1                0.687469198*QGAS + 9.0145E-7*QGAS**2)             F
     IF(ABS(QGLY-QGAS).LT.XK(407)) GO TO 450                           F
     ISGNSV=ISGN                                                       F
     IF(QGLY.LT.QGAS) ISGN=+1                                          F
     IF(QGLY.GT.QGAS) ISGN=-1                                          F
     TINCR=DTEMP*ISGN                                                  F
     IF(ISGN.EQ.ISGNSV) GO TO 440                                      F
     XK(I+331)=T2OLD                                                   F
     XK(I+388)=T4OLD                                                   F
     DTEMP=DTEMP/2.0                                                   F
     INDEX2 = INDEX2 + 1                                               F
     GO TO 310                                                         F
 440 XK(I+388)=XK(I+388)+TINCR                                         F
     INDEX2 = INDEX2 + 1                                               F
     GO TO 310                                                         F
445  WRITE (6, 446)                                                    F
446  FORMAT (1H0, 74HCONDENSER HEAT BALANCE NOT COMPLETED WITHIN SPECIFF
    1IED NUMBER OF ITERATIONS)                                         F
 450 QCOND(I)=QGAS                                                     F
     IF(I-2) 451,452,453                                               F
 451       SLPARY(K893,A60)
     GO TO 700                                                         F
 452       SLPARY(K894,A61)
     GO TO 700                                                         F
 453       SLPARY(K895,A62)
      REM  END OF LOOP*******************************
 700 CONTINUE                                                          F
     INDEX1 = 1                                                        F
      REM**********************************************************************
      END
      BCD 3OUTPUT CALLS
     COMMON/BRAVO/QCOND(3),DMASS(3),WTH230(3)                          F
     COMMON/CHARLE/ J, M, N                                            F
     COMMON/ECHO/ IPOINT                                               F
     COMMON/FOXTRT/ PCKOH(3)                                           F
     DIMENSION ATEMP(50)                                               F
     DIMENSION XK(1)                                                   F
     DIMENSION CRTAR1(200), CRTAR2(200), CRTAR3(200), CRTAR4(200),     F
    1 CRTAR5(72), CRTAR6(72), CRTAR7(63)                               F
     DIMENSION DATE(2)                                                 F
     DATA ITIT/0/                                                      F
     DATA CRTAR5/ 'MISS','ION ','TIME',' - ',' MIN', 13*'    '/        F
     DATA CRTAR6/ 'SYST','EM T','EMPE','RATU','RES ',' .  ','DEG ',    F
    1 'F   ', 10*'    '/                                               F
     EQUIVALENCE (XK(1),K(1))                                          F
     CALL CAMRAV(9)                                                    F
     TIME = 0.0                                                        F
     DO  100  N1 = 1, 63                                               F
     CRTAR7(N1) = TIME                                                 F
     TIME = TIME + 3.0                                                 F
100  CONTINUE                                                          F
      REM SOLVE FOR RADIATOR PRESSURE DROP
          MLTPLY(K6,K6,K585,K682) $RADIATOR PRESSURE DROP FOR SYSTEM 1
          MLTPLY(K7,K7,K589,K683) $RADIATOR PRESSURE DROP FOR SYSTEM 2
          MLTPLY(K8,K8,K593,K684) $RADIATOR PRESSURE DROP FOR SYSTEM 3
          D1DEG1(K682,A84,K6)          $  FLOW RATE  -  SYSTEM 1
          D1DEG1(K683,A84,K7)          $  FLOW RATE  -  SYSTEM 2
          D1DEG1(K684,A84,K8)          $  FLOW RATE  -  SYSTEM 3
      REM FLUID HEAT LOSS FOR SYSTEM 1
          QMTRI(16,A9+1,G601,A25+1)
      REM FLUID HEAT LOSS FOR SYSTEM 2
          QMTRI(16,A9+19,G619,A25+17)
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```
  REM FLUID HEAT LOSS FOR SYSTEM 3
       QMTRI(16,A9+37,G637,A25+33)
  IF(K(9).EQ.1) GO TO 1                                                    F
       SUMARY(16,A25+1,K801)
  GO TO 2                                                                  F
1 CONTINUE                                                                 F
       SUMARY(10,A25+1,K801)
2 IF(K(10).EQ.1) GO TO 3                                                   F
       SUMARY(16,A25+17,K802)
  GO TO 4                                                                  F
3 CONTINUE                                                                 F
       SUMARY(10,A25+17,K802)
4 IF(K(11).EQ.1) GO TO 5                                                   F
       SUMARY(16,A25+33,K803)
  GO TO 6                                                                  F
5 CONTINUE                                                                 F
       SUMARY(10,A25+33,K803)
6 CONTINUE                                                                 F
  CALL DATOUT                                                              F
  WRITE(6,11)                                                              F
11 FORMAT(5X,99HSYSTEM   POWER   CURRENT   VOLTAGE   TSI      TSE         F
 1  TCIP     TCEP     QCOND     W-COND   WS-RATE, 3X,                      F
 2 12HTO2     TH2)                                                         F
  WRITE(6,12)                                                              F
12 FORMAT(14X,90HWATTS     AMPS     VOLTS     DEGF     DEGF      DEGF      F
 1   DEGF      BTU/HR      LB/HR    PERCENT, 3X, 12HDEGF     DEGF, /)      F
  DO 13 I=J,M,N                                                            F
13 WRITE(6,14) I,XK(I+412),XK(I+349),XK(I+353),XK(I+339),XK(I+342),       F
 1            XK(I+371),XK(I+331),QCOND(I),XK(I+450),XK(I+453),           F
 2 XK(I + 463), XK(I + 466), PCKOH(I)                                      F
14  FORMAT(6X,I2,4X,2F8.2,1X,5F0.2,F10.2,F10.3,2F9.2,F8.2,F9.3)            F
  WRITE (6, 15)                                                            F
15  FORMAT (//)                                                            F
  WRITE(6,16)                                                              F
16 FORMAT(5X,114HSYSTEM   FLOW RATE   QRAD    TRADIN   TRADOUT   DPRAF
 1D    TSRCI    TSRCE     TSRHI    TSRHE     TCIS      TCES     BPFSI    F
  WRITE(6,17)                                                              F
17 FORMAT(16X,95HLB/HR     BTU/HR     DEGF      DEGF      PSIA     DEGF    F
 1   DEGF      DEGF      DEGF      DEGF      DEGF, /)                       F
  DO 18 I=J,M,N                                                            F
18 WRITE(6,19) I,XK(I+5),XK(I+296),T(I+243),T(I+240),XK(I+212),           F
 1            XK(I+385),XK(I+377),XK(I+391),XK(I+394),XK(I+403),          F
 2            XK(I+388),XK(I+374)                                         F
19 FORMAT(6X,I2,5X,F8.2,1X,2F9.2,F10.2,F8.3,6F9.2,F8.4)                   F
  WRITE (6, 20)                                                            F
20  FORMAT(//7X,120HPANEL  1         PANEL  2         PANEL  3        PAF
 1NEL  4         PANEL  5         PANEL  6         PANEL  7        PANEF
 2L  8, /, 5X, 123HIN      OUT      IN      OUT      IN      OUT     IF
 3N     OUT     IN      OUT      IN      OUT      IN      OUT      IN F
 4    OUT, /)                                                              F
  DO  21  I1 = 193,208                                                     F
  J1 = 209 - I1                                                            F
21  ATEMP(J1) = T(I1)                                                      F
  DO  22  I2 = 209,224                                                     F
  J2 = 241 - I2                                                            F
22  ATEMP(J2) = T(I2)                                                      F
  DO  23  I3 = 225,240                                                     F
  J3 = 273 - I3                                                            F
23  ATEMP(J3) = T(I3)                                                      F
  WRITE (6, 25)  (ATEMP(KT), KT =  1, 16)                                  F
  WRITE (6, 25)  (ATEMP(KT), KT = 17, 32)                                  F
  WRITE (6, 25)  (ATEMP(KT), KT = 33, 48)                                  F
25  FORMAT (1X, 16F8.1)                                                    F
  NP = 125                                                                 F
```

```
      CRTAR1(IPOINT) = XK(343)                                           F
      CRTAR2(IPOINT) = XK(332)                                           F
      CRTAR3(IPOINT) = T(244)                                            F
      CRTAR4(IPOINT) = T(241)                                            F
      IF (IPOINT.EQ.NP)  GO TO 30                                        F
      IPOINT = IPOINT + 1                                                F
      GO TO 50                                                           F
 30   CONTINUE                                                           F
      IF (ITIT.EQ.0)  CALL CDATEV(DATE)                                  F
      IF (ITIT.GT.0)  GO TO 50                                           F
      CALL GRF3TV(-1,38,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR1(1),200.,0.,      F
     1 500.,0.)                                                          F
      CALL RITE2V(331,1010,1023,90,2,20,1,'SYSTEM 1  -  30 AMPS',IBLY)   F
      CALL PRINTV(8,DATE,943,995)                                        F
      CALL GRF3TV( 0,63,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR2(1),200.,0.,      F
     1 500.,0.)                                                          F
      CALL GRF3TV( 0,55,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR3(1),200.,0.,      F
     1 500.,0.)                                                          F
      CALL GRF3TV( 0,44,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR4(1),200.,0.,      F
     1 500.,0.)                                                          F
      CALL GRF3TV(-1,38,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR1(63),200.,0.,     F
     1 500.,0.)                                                          F
      CALL RITE2V(331,1010,1023,90,2,20,1,'SYSTEM 1  -  25 AMPS',IBLY)   F
      CALL PRINTV(8,DATE,943,995)                                        F
      CALL GRF3TV( 0,63,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR2(63),200.,0.,     F
     1 500.,0.)                                                          F
      CALL GRF3TV( 0,55,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR3(63),200.,0.,     F
     1 500.,0.)                                                          F
      CALL GRF3TV( 0,44,CRTAR5,CRTAR6,-63,CRTAR7,CRTAR4(63),200.,0.,     F
     1 500.,0.)                                                          F
      ITIT = 2                                                           F
 50   CONTINUE                                                           F
       END
```

USER SUBROUTINE LISTINGS

```
      SUBROUTINE CNVLTN(DT,V1,NST,NFCN,V2)
      DOUBLE PRECISION DTOP,DTNS,V1J,V1JP1,VAV,TMT,TMTO,V2DP,XSFER,
     1                 SCALE,RISB,RMXSB
      DIMENSION DT(1),V1(1)
      EQUIVALENCE(D,N)
C
C     V1 MUST BE DIMENSIONED NOT LONGER THAN
C     (DIMENSION OF DT)+1
C
      D = DT(1)
      IDT = N
      D = V1(1)
      IV1 = N
      NT = IDT+1-IV1
      IF(NT) 169,5,5
    5 IF(NST) 15,15,25
   15 NST = IDT+1
   25 V2DP = 0.0000
      TMT = 0.0000
C     ******************************************************************
      MXSB = 10
C     ******************************************************************
      RMXSB = MXSB
      NSTM1 = NST-1
      DO 80 I=1,NSTM1
      J = NST-I+1
      DTDP = DT(J)
      JS = J-NT
      V1J = V1(JS)
      V1JP1 = V1(JS+1)
      DTNS = DTDP/RMXSB
      TMTO = TMT
      DO 70 ISB=1,MXSB
      IF(ISB-1) 30,30,40
   30 TMT = TMT+0.5000*DTNS
      GO TO 45
   40 TMT = TMT+DTNS
   45 RISB = ISB
      SCALE = RISB/RMXSB
      VAV = V1JP1+(V1JP1-V1J)*SCALE
   70 V2DP = V2DP+XSFER(NFCN,TMT)*VAV*DTNS
      TMT = TMTO+DTDP
   80 CONTINUE
      V2 = V2DP
      RETURN
  169 WRITE(6,170)
  170 FORMAT(43H ERROR IN DIMENSIONING OF ARRAYS FOR CNVLTN)
      RETURN
      END
```

```
      SUBROUTINE CNVLTE(DT,V1,GAIN,NST,NFCN,V2)
      DOUBLE PRECISION DTDP,DTNS,V1J,V1JP1,VAV,GJ,GJP1,GAV,TMT,TMTO,
     1                 V2DP,XSFER,SCALE,RISB,RMXSB
      DIMENSION DT(1),V1(1),GAIN(1)
      EQUIVALENCE(D,N)
C
C     V1 AND GAIN MUST BE DIMENSIONED EQUAL LENGTH AND MAY
C     NOT BE LONGER THAN (DIMENSION OF DT)+1
C
      D = DT(1)
      IDT = N
      D = V1(1)
      IV1 = N
      D = GAIN(1)
      IG = N
      NT = IDT+1-IV1
      IF(NT) 169,5,5
    5 NT = IDT+1-IG
      IF(NT) 169,10,10
   10 IF(IG-IV1) 169,15,169
   15 IF(NST) 20,20,25
   20 NST = IDT+1
   25 V2DP = 0.0D00
      TMT = 0.0D00
C     ***************************************************************
      MXSB = 10
C     ***************************************************************
      RMXSB = MXSB
      NSTM1 = NST-1
      DO 80 I=1,NSTM1
      J = NST-I+1
      DTDP = DT(J)
      JS = J-NT
      V1J = V1(JS)
      V1JP1 = V1(JS+1)
      GJ = GAIN(JS)
      GJP1 = GAIN(JS+1)
      DTNS = DTDP/RMXSB
      TMTO = TMT
      DO 70 ISB=1,MXSB
      IF(ISB-1) 30,30,40
   30 TMT = TMT+0.5D00*DTNS
      GO TO 45
   40 TMT = TMT+DTNS
   45 RISB = ISB
      SCALE = RISB/RMXSB
      VAV = V1JP1+(V1JP1-V1J)*SCALE
      GAV = GJP1+(GJP1-GJ)*SCALE
   70 V2DP = V2DP+XSFER(NFCN,TMT)*VAV*GAV*DTNS
      TMT = TMTO+DTDP
   80 CONTINUE
      V2 = V2DP
      RETURN
  169 WRITE(6,170)
  170 FORMAT(43H ERROR IN DIMENSIONING OF ARRAYS FOR CNVLTE)
      RETURN
      END
```

```
      SUBROUTINE DELAY1(TAR, ARR, TAU, VAL, INDX)
      DIMENSION TAR(1), ARR(1)
      EQUIVALENCE(D,N)
      D = TAR(1)
      ITAR = N + 1
      D = ARR(1)
      IARR = N + 1
      JTAR = ITAR
      JARR = IARR
      DT = TAU - TAR(JTAR)
   10 JTAR = JTAR - 1
      IF (JTAR - 2)  100, 20, 20
   20 JARR = JARR - 1
      IF (JARR - 2)  200, 30, 30
   30 IF (DT)  60, 60, 40
   40 DT = DT - TAR(JTAR)
      GO TO 10
   60 INDX = JARR
      VAL = ARR(JARR)
      RETURN
C
C     ERROR MESSAGES
C
  100 WRITE (6, 101)
  101 FORMAT (50H DELAY1 ERROR--TAU EXCEEDS SUM OF SAVED TIME STEPS)
      INDX = 2
      VAL = ARR(2)
      RETURN
  200 WRITE (6, 201)
  201 FORMAT (28H DELAY1 ERROR--ARR TOO SMALL)
      INDX = 2
      VAL = ARR(2)
      WRITE (6, 250)  DTIMEU
  250 FORMAT (12HTHE TIME IS ,  F10.5)
      RETURN
      END
      SUBROUTINE DELAY2(TAR, ARR, TAU, VAL, INDX)
      DIMENSION TAR(1), ARR(1), TAU(1)
      EQUIVALENCE(D,N)
C
C     TAR MUST BE DIMENSIONED ONE LESS THAN ARR AND TAU
C
      D = TAR(1)
      ITAR = N
      D = ARR(1)
      IARR = N
      D = TAU(1)
      ITAU = N
      SUMDT = 0.0
      TAUITG = 0.0
      J = ITAR + 1 - IARR
      IF(J)  69,10,69
   10 IF(IARR - ITAU) 69,20,69
   20 DO  50  I = 1,ITAR
      M = ITAR + 2 - I
      SUMDT = SUMDT + TAR(M)
      TAUAVI = (TAU(M) + TAU(M + 1))/2.0
      TAUITG = TAUITG + TAUAVI*TAR(M)
      TAUAVC = (1./SUMDT)*TAUITG
      IF (SUMDT - TAUAVC)  50, 60, 60
   50 CONTINUE
      WRITE (6, 51)
```

```
   51 FORMAT (43H MEAN TAU OUT OF RANGE OF TAR SUM IN DELAY2)
   60 VAL = ARR(M)
      INDX = M
      RETURN
   69 WRITE (6, 70)
   70 FORMAT (43H ERROR IN DIMENSIONING OF ARRAYS FOR DELAY2)
      RETURN
      END
```

```
      SUBROUTINE SLPARY(ARYN,ARY)
      DIMENSION ARY(1)
      EQUIVALENCE(D,N)
      D=ARY(1)
      IC=N
      DO 10 I=2,IC
   10 ARY(I)=ARY(I+1)
      ARY(IC+1)=ARYN
      RETURN
      END
```

```
      SUBROUTINE ARYSTO(N,X,A)
      DIMENSION A(1)
      X = A(N)
      RETURN
      END
```

```
      DOUBLE PRECISION FUNCTION XSFER(NFCN,T)
      DOUBLE PRECISION T
      XSFER = 0.0D00
C     ****************************************************************
C     NFCN=1 IS SECONDARY REGENERATOR FUNCTION
      IF(NFCN.NE.1) GO TO 10
      IF(T.GT.0.5277D00) RETURN
      XSFER = (1.D00/0.5277D-02)*DEXP(-T/0.5277D-02)
      RETURN
C     ****************************************************************
   10 CONTINUE
C     ****************************************************************
C     NFCN=2 IS SECONDARY BYPASS VALVE FUNCTION
      IF(NFCN.NE.2) GO TO 20
      IF(T.GT.0.2833D00) RETURN
      XSFER = (1.D00/0.2833D-02)*DEXP(-T/0.2833D-02)
      RETURN
C     ****************************************************************
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DATOUT
      COMMON/FIXCON/ N
      DIMENSION N(1)
      IF (N(28).GE.58.OR.N(29).EQ.0)  CALL HEADNG
      N(29) = N(28) + 4
      WRITE (6, 100)  N(1), N(2), N(35), N(17), N(36), N(15), N(37),
     1 N(30)
  100 FORMAT (/1X, 10H*  *  *  */1X, 4HTIME, 1PE13.5, 1X, 6HDTIMEU,
     1 1PE13.5, 1X, 7HCSGMIN(, I5, 1H), 1X, 1PE13.5, 1X, 7HDTMPCC(, I5,
     2 1H), 1X, 1PE13.5, 1X, 7HARLXCC(, I5, 1H), 1X, 1PE13.5 //)
      RETURN
      END
```

```
      SUBROUTINE HEADNG
      COMMON/FIXCON/ N
      COMMON/TITLE/ H
      DIMENSION N(1), H(20)
      N(28) = 15
      N(29) = N(29) + 1
      WRITE (6, 100) N(29), H
  100 FORMAT (1H1, 116X, 4HPAGE, 2X, I7 / 4X, 121HSYSTEMS IMPROVED NUMER
     1ICAL DIFFERENCING ANALYZER   *   SINDA   *   NORTH AMERICAN ROCKWE
     2LL CORPORATION  -  SPACE DIVISION, //, 5X, 20A6//)
      RETURN
      END
```

```
      SUBROUTINE GRF3TV(L,ISYM,BCDX,BCDY,NP,X,Y,XMAX,XMIN,YMAX,YMIN)    GRF00010
C                                                                       GRF00020
C     GRAF3V PLOTS 1,2, OR 3 GRIDS PER PAGE ON THE SC 4020              GRF00030
C                                                                       GRF00040
C     *** NOTATION ***                                                  GRF00050
C                                                                       GRF00060
C     L       NO. OF GRAPHS PER FRAME(1,2,OR3).                         GRF00070
C             IF L IS NEGATIVE - FRAME WILL BE ADVANCED AND NP POINTS   GRF00080
C             WILL BE PLOTTED ON GRID NO.1                              GRF00090
C             IF L IS POSITIVE - NP POINTS WILL BE PLOTTED ON GRID 2 OR 3GRF00100
C             IF L IS ZERO - NP POINTS WILL BE PLOTTED ON PREVIOUS GRID GRF00110
C                                                                       GRF00120
C     ISYM    PLOTTING SYMBOL                                           GRF00130
C                                                                       GRF00140
C     BCDX    ALPHA-NUMERIC CHARACTERS FOR THE X AXIS & Y AXIS.  THESE  GRF00150
C     BCDY    ARRAYS ARE LIMITED TO 72 CHARACTERS EACH AND THE LAST     GRF00160
C                                                                       GRF00170
C     NP      NUMBER OF POINTS TO BE PLOTTED                            GRF00180
C             IF NP IS NEGATIVE - THE POINTS WILL BE CONNECTED, THUS THE GRF00190
C             VALUES OF X MUST BE IN ASCENDING ORDER                    GRF00200
C                                                                       GRF00210
C     XMAX    MAXIMUM & MINIMUM VALUES OF X & Y.  IF BOTH MINIMUM AND   GRF00220
C     XMIN    MAXIMUM VALUES OF X ARE ZERO, THE ARRAY IS SEARCHED FOR   GRF00230
C     YMAX    THE APPROPRIATE VALUES.  THE SAME PROCEDURE IS FOLLOWED   GRF00240
C     YMIN    FOR MINIMUM & MAXIMUM Y                                   GRF00250
C                                                                       GRF00260
      DIMENSION X(500),Y(500),BCDX(18),BCDY(18)                         GRF00270
      NZ = IABS(NP)                                                     GRF00275
      IF(NZ .EQ. 0) GO TO 60                                            GRF00280
      IF(L .EQ. 0 ) GO TO 30                                            GRF00290
      XL = XMIN                                                         GRF00300
      XR = XMAX                                                         GRF00310
      IF((XL .NE. 0.0) .OR.  (XR .NE. 0.0)) GO TO 15                    GRF00320
      XL = X(1)                                                         GRF00325
      XR = X(1)                                                         GRF00326
      DO 10 K = 1,NZ                                                    GRF00330
      XL = AMIN1(X(K),XL)                                               GRF00340
   10 XR = AMAX1(X(K),XR)                                               GRF00350
   15 YB = YMIN                                                         GRF00360
      YT = YMAX                                                         GRF00370
      IF((YT .NE. 0.0) .OR.  (YB .NE. 0.0)) GO TO 25                    GRF00380
      YB = Y(1)                                                         GRF00385
      YT = Y(1)                                                         GRF00386
      DO 20 J = 1,NZ                                                    GRF00400
      YB = AMIN1(Y(J),YB)                                               GRF00410
   20 YT = AMAX1(Y(J),YT)                                               GRF00420
   25 IF(L .LT. 0 ) L1 = 1                                              GRF00440
      IF(L .GT. 0 ) L1 = 2                                              GRF00450
      NCX = NBLANC(BCDX,18)                                             GRF00460
      NCY = NBLANC(BCDY,18)                                             GRF00470
      LGO = IABS(L)                                                     GRF00480
      DCX = 10.0                                                        GRF00490
      DCY = 10.0                                                        GRF00500
      INCRY = -14                                                       GRF00510
      CALL MARGNP (L,ICY)                                               GRF00520
      IX = 524 - 4*NCX                                                  GRF00530
      IY = ICY +7*NCY                                                   GRF00540
      IF(LGO .EQ. 1) IY1 = 0                                            GRF00550
      IF(LGO .EQ. 2) IY1 = ICY - 253                                    GRF00560
      IF(LGO .EQ. 3) IY1 = ICY - 169                                    GRF00570
      CALL DXDYV(1,XL,XR,DX,N,I,NX,DCX,IER)                             GRF00580
      CALL DXDYV(2,YB,YT,DY,M,J,NY,DCY,IER)                             GRF00590
      CALL GRIDIV(L1,XL,XR,YB,YT,DX,DY,N,M,I,J,NX,NY)                   GRF00600
      CALL PRINTV(NCX,BCDX,IX,IY1)                                      GRF00610
      CALL APRNTV(0,INCRY,NCY,BCDY,0,IY)                                GRF00620
   30 CALL APLOTV(NZ,X,Y,1,1,1,ISYM,IER)                                GRF00640
      IF (NP .GT. 0) GO TO 60                                           GRF00650
      DO 50 KK = 1,NZ                                                   GRF00660
      NXA = NXV(X(KK))                                                  GRF00670
      NYA = NYV(Y(KK))                                                  GRF00680
      IF(KK .LT. 2) GO TO 40                                            GRF00690
      CALL LINEV(NXO,NYO,NXA,NYA)                                       GRF00700
   40 NXO = NXA                                                         GRF00710
      NYO = NYA                                                         GRF00720
   50 CONTINUE                                                          GRF00730
   60 RETURN                                                            GRF00740
      END                                                               GRF00750
```

```
      SUBROUTINE MARGNR(L1,ML3)
C
C     'MARGNR' SETS THE MARGINS FOR PLOTTING 1,2, OR 3 GRIDS PER FRAME
C
      DIMENSION L(6,3),IN(3)
      DATA L /24,357,690,24,524,24,690,357,24,524,24,24,178,511,844,262,
     1        762,512/, IN /5,3,0/
      IF( L1 .GE. 0 ) GO TO 10
         K = -L1
         N = 1
   10 IC = N + IN(K)
      ML3 = L(IC,3)
      CALL SETMIV(24,0,L(IC,1),L(IC,2))
      N = N + 1
      RETURN
      END
```

```
      FUNCTION NBLANC(WORD,N)
C
C     'NBLANC' DETERMINES NO. OF CHARACTERS IN A HOLLERITH LABEL
C             IF THERE ARE NO CHARACTERS, NBLANC = 0
C
      DIMENSION WORD(18)
      DATA BLANK /'    '/
      DO 10 M = 1,N
        I = N - M
        IF((WORD(I)-BLANK) .NE. 0.0) GO TO 20
   10 CONTINUE
      I = 0
   20 NBLANC = 4*I
      RETURN
      END
```